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THE BRITISH JOURNAL OF METALS

Vol. 56 No. 336 OCTOBER, 1957 Monthly: Two Shillings and Sixpence

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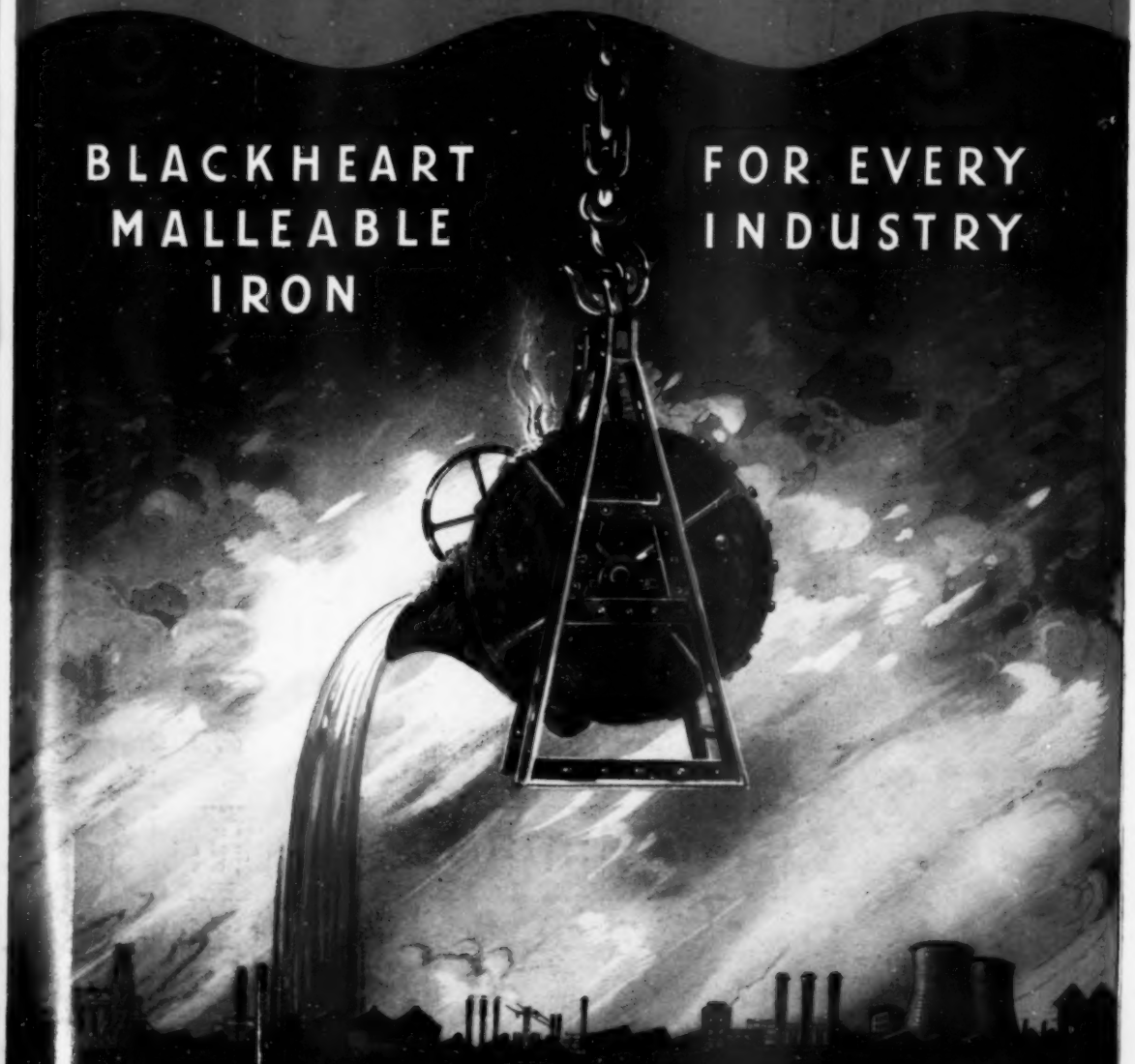

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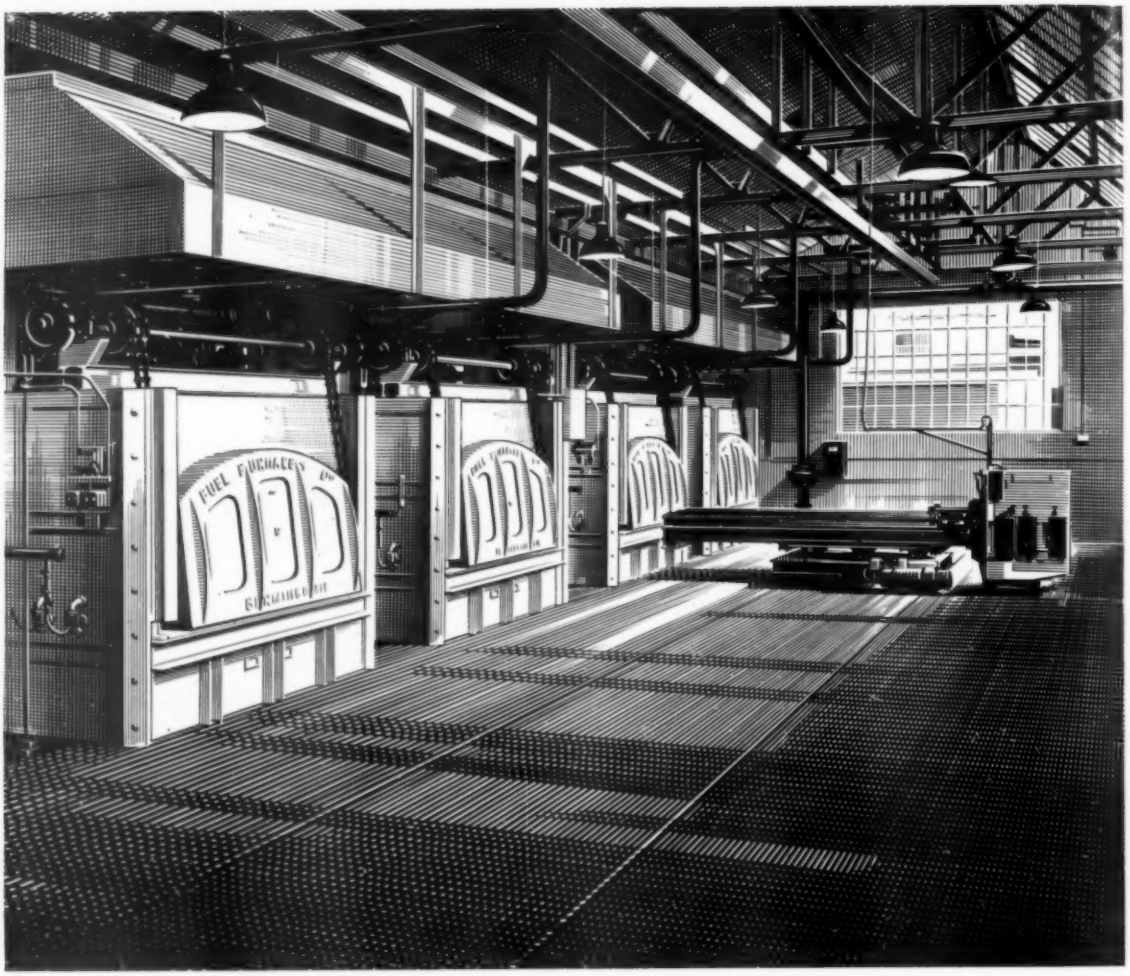

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THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

CONTENTS FOR OCTOBER, 1957 Vol. 56 No. 336

PUBLISHED MONTHLY BY

The Kennedy Press, Ltd.,
31, King Street West,
Manchester, 3.
Telephone : BLAckfriars 2084

London Office :

158, Temple Chambers,
Temple Avenue, E.C.4.
FLEet Street 8914

CONTRIBUTIONS

Readers are invited to submit articles for publication in the editorial pages: photographs and/or drawings suitable for reproduction are especially welcome. Contributions are paid for at the usual rates. We accept no responsibility in connection with submitted manuscript. All editorial communications should be addressed to The Editor, "Metallurgia," 31, King Street West, Manchester, 3.

SUBSCRIPTIONS

Subscription Rates throughout the World—30/- per annum, Post free.

ADVERTISING

Communications and enquiries should be addressed to the Advertisement Manager at Manchester.

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

OCTOBER, 1957 Vol. LVI. No. 336

Some Trends in European Steel

FOLLOWING the practice of recent years, the Secretariat of the Economic Commission for Europe has issued a report on the European Steel Market in 1956,* and whilst space requirements preclude a discussion of all the features involved, the current proposals for European Free Trade give added interest to the plans for the expansion of steel production in Western Europe, which is expected to continue at a high rate. The most striking point which emerges from a study of the figures for percentage increases in crude steel production (actual or planned) between 1949 and 1960, is that from 1949 until the present time, and as expected until 1960, the rate of growth has been, and seems likely to continue to be, fairly steady, with surprisingly little difference between the main producing countries throughout the world.

Now that many existing iron and steel works are nearing the limit of expansion, for one reason or another, plans are being made for laying down works on virtually green-field sites. Many existing works owe their location to the proximity of an ore or coal field, but there is a marked tendency for new works to be located near the coast. It is expected new coastal works producing 5·5 million tons will be in operation by 1960, adding 5% to the total production in Western Europe. The main factor in the choice of site appears to have been accessibility by sea both to imported raw materials and potential markets. This is a natural consequence of the growing need to rely on overseas ore supplies, which has led to the intensive prospecting in Africa and North America in recent years.

The investment costs incurred in laying down a 1m. tons per annum plant on a green site are considerably greater than those involved in achieving the same increase in output by expanding existing works. It is not surprising, therefore, to learn that the new coastal works will be responsible for only a quarter of the increase in output anticipated by 1960. There is, therefore, a tendency to attempt to increase output at an existing plant, either by increasing its size or improving its operating efficiency. Much has been done, for instance, to increase the output of existing blast furnaces and steel furnaces, an important development being the continuing rapid growth in the production of sinter, which has more than doubled since 1950 for Western Europe as a whole.

An important trend designed to obtain more output from existing plant in relation to qualities of raw materials and fuel available is the increasing production of iron obtained direct from ore. At the Salzgitter plant in Western Germany, production of Krupp-Renn lupper is expected to rise from 100,000 tons in 1957 to 400,000 tons in 1960, and another plant is to be erected in Westphalia with a capacity of 400,000 tons. Other projected plants to operate this process include two in Spain with a combined annual output of 80,000 tons, and one in Portugal with a capacity of 120,000 tons due to go into production in 1964. There are also plans for small plants in Greece and Turkey. Production of sponge iron in Sweden has increased from an annual figure of 40,000 tons in 1951 to 122,000 tons in 1956, and is expected to reach 200,000 tons by the end of this year : there are also plans for two sponge iron plants in Spain.

A further trend of considerable importance—also with a view to improved production from existing plant—is the increased use of oxygen in steel making, which has been facilitated by the availability of cheap oxygen from tonnage plants. One method of using oxygen in steel making which has made rapid strides in the last few years is the L-D (Linz-Donawitz) process, the output from which in Austria increased from 322,000 tons in 1953 to 845,000 tons in 1956 : 1m. tons are expected to be produced in this way by 1960. Plant is being installed for the process in the Netherlands and Western Germany. Other projected plants outside Western Europe will be located in Brazil, Canada, Czechoslovakia, Hungary, India, Japan, Roumania and the United States.

Full details regarding other oxygen-using processes, such as the Kaldo and Rotor techniques, are incomplete, but production in top-blown vessels is expected to reach 450,000 tons in 1957, and Poland is installing oxygen-using steel making facilities aimed at a 1962 production of 1m. tons. In the United Kingdom several variants of oxygen-using processes are being applied. An oxygen-blown converter in one works is to be followed by the installation of oxygen-blowing facilities at three other works. Oxygen is also being used in the United Kingdom for pre-refining blast furnace metal before charging it into the open hearth furnaces. The production of oxygen blown steel in Sweden is expected to expand in the near future, and there is already a substantial production in both Belgium and Luxembourg.

On the rolling mill side, considerable attention has been, and is being, devoted to the production of plates, which have been in short supply in recent years. Expansion of plate rolling capacity has been mainly in the form of modern four-high mills. In Western Germany five new mills came into production between 1954 and 1956 (two replacing old mills), and two new four-high mills replaced old plant in France/Saar. A new mill came in in Italy at the end of 1956, and a new Austrian mill is expected to be in operation by the end of this year or the beginning of next. In the United Kingdom some six new modern mills are due to be installed between 1958 and 1962. The easing of the market for sheets has led to the use of wide strip mills for plate production, and although a number of technical difficulties arise through the insufficiency of shearing and handling facilities, these are being overcome in some works by modifications to the plant designed to cope with the thicker material.

* Copies may be obtained from H.M. Stationery Office, price 5s. 6d.

Personal News

METROPOLITAN-VICKERS ELECTRICAL EXPORT CO., LTD., announces the appointment of MR. P. O'B. HOVE as Resident Manager, Middle East. He will be located in Baghdad, Iraq.

MR. A. M. A. MAJENDIE and MR. L. C. HARMAN have been appointed to the Board of Smiths Aircraft Instruments, Ltd.

MR. J. W. LAMBERT, who was recently awarded the Insignia Award in Technology of the City and Guilds of London Institute, has been appointed Works Manager to the Alloys Division of Union Carbide, Ltd. His responsibility includes the production of high carbon ferrochromium, briquetted and graded alloys, and exothermic alloys at the Company's Sheffield and Glossop plants.

METROPOLITAN-VICKERS ELECTRICAL CO., LTD., announces the appointment of MR. R. CLOUGH, Superintendent, Switchgear Department, as Assistant Works Manager (Inventory Control), in which capacity he will be concerned with inventory in all establishments controlled by the Company. MR. J. HARWOOD succeeds Mr. Clough as Superintendent, Switchgear Department.

MR. A. E. PEARCE, Chairman of Dartmouth Auto Castings, Ltd., Smethwick, retired in July. Mr. Pearce, who had been associated closely with other companies in the Birmid Group, had been a Director of the Company since its inception in 1934. He had wide interests in the foundry world, being a member of the Council of the British Cast Iron Research Association and also of the Council of Ironfoundry Associations.

THE President of the Board of Trade has appointed MR. W. R. BLACK, J.P., to be Chairman of the National Research Development Corporation in succession to the late Chairman, Sir Alan Saunders, who died in February.

MR. V. WATKINS has been appointed a Director of Steel, Peech and Tozer, a branch of The United Steel Cos., Ltd. Mr. Watkins joined the company in 1943, and has been Chief Engineer since 1953.

MR. G. G. ROBERTS, formerly Director of Research to Smiths Aircraft Instruments, Ltd., at Cheltenham, has now been appointed Technical Director, upon the resignation of MR. E. B. MOSS.

AT the June Examinations of the Institute of Cost and Works Accountants, the Donald L. Moran Prize for first place in the Management (Factory and Distribution) Section of the Final Examination was awarded to MR. C. J. JAMES, of the South Wales Aluminium Co., Ltd., Resolven. In the Intermediate Examination, MR. G. F. GROOM, of John Lysaght's Scunthorpe Works, Ltd., gained first place and was awarded the George Russell Memorial Prize.

DR. W. HUME-ROTHERY, F.R.S., is to be elected to Honorary Life Membership of the American Society for Metals at the Society's 39th National Metal Exposition and Congress to be held in Chicago in November.

MR. H. E. CORNISH, O.B.E., M.C., former Post Master General of Sarawak, has been appointed General Manager of British Telecommunications Research, Ltd., the research establishment jointly sponsored by Automatic Telephone & Electric Co., Ltd., and British Insulated Callender's Cables, Ltd., at Taplow (Bucks).

MR. H. M. HENDERSON, General Sales Manager of The United Steel Cos., Ltd., is leaving this country to take charge of the company's interests in Patchett Steel Construction (Pty.), Ltd., of Cape Town. Mr. Henderson will be succeeded by MR. R. P. CRAWSHAW, who will continue his duties as the Chief Purchasing Agent of United Steel.

MR. G. D. DENYER, has joined the staff of Aluminium Laboratories, Ltd., Banbury as Head of the Casting Section of the Metallurgy Division, and MR. L. ROULLIER has been appointed Head of the recently formed Electrical Division.

SIR MILES THOMAS, Chairman of Monsanto, Ltd., is to join the British Productivity Council. He has been nominated by the Federation of British Industries to succeed SIR EWART SMITH, who has resigned after serving on the Council since its inception in 1952.

MR. R. J. HARBORD, son of Mr. V. Harbord, has joined Riley, Harbord and Law, consulting metallurgists and chemists, as a Partner.

MR. E. E. JONES, Group Commercial Director of The Solartron Electronic Group, Ltd., and Vice-President of Solartron Incorporated of Los Angeles, U.S.A., left on September 15th for a stay of some months in the United States.

MR. E. D. ROBINSON, formerly Assistant Manager of London Area Sales Office of Northern Aluminium Co., Ltd., has taken up the appointment of Area Sales Manager in charge of the Manchester Office in succession to MR. D. A. CORBETT-THOMPSON who, as previously announced, has been appointed Sales Manager in charge of Export Sales. MR. M. BRIDGEWATER, who has just completed a year's study at the Centre d'Etudes Industrielles, Geneva, becomes Manager of the Sales Development Division, Banbury, with effect from September 30th 1957. He succeeds MR. E. D. ILIFF who, as already announced, has been appointed Sales Manager in charge of Sales Development, Advertising and Publicity. Mr. Bridgewater was previously in charge of the building and construction section of the Sales Development Division.

MR. E. C. S. GREAVES who has been with General Refractories, Ltd., for 26 years, and has for some years been North Western Area Sales Manager, has been appointed to the position of Home Sales Manager and will operate from Head Office at Sheffield. He is succeeded as North Western Area Sales Manager by MR. E. C. BRAMPTON, who has held a senior position in the Technical Service Division of the Company for 17 years. MR. G. G. ABRAHAM has been appointed to the position of Technical Service Manager at Head Office, and is succeeded by MR. J. G. WATSON as North Eastern Area Sales Manager.

MR. G. SMELLIE of the Steel Company of Wales, who was until recently Works Manager of the Company's Steel Division, has been seconded by his Company to the British Iron and Steel Federation to act as Director, British Iron and Steel Federation Management Courses at Ashorne Hill, Nr. Leamington Spa. MR. H. I. COZENS, C.B., A.F.C., who recently retired from the Royal Air Force as Air Commodore, has been appointed Deputy Director.

MR. W. MCLELLAND, who since 1945 has been Foundry Manager at the Blackheath Works of Firth-Vickers Stainless Steels, Ltd., has been appointed Area Sales Manager (Scotland and North East England) by

(Continued on page 192)

An Examination of Oxide Films on Tin and Tinplate

By S. C. Britton and K. Bright

The Tin Research Institute

The oxide films formed on tin and tinplate in air at various temperatures and in passivating solutions have been studied by controlled cathodic reduction which gives information about their rate of growth, and by examination of films detached from the metal to obtain evidence of their composition. Although the films formed in chromatic solutions depend for their chemical resistance on the chromium compounds they contain, their growth can be estimated by cathodic reduction of the tin constituent.

THE thin layers which are formed on tin and tinplate exposed to oxidising conditions, generally referred to as "oxide films," have considerable industrial importance. Such layers may be either useful or harmful. Useful types protect the metal and are often produced deliberately by suitable chemical or electro-chemical treatment. Harmful types, usually forming adventitiously during storage or during the stoving of lacquers, may discolour the metal, adversely affect the adhesion of lacquers, and even promote corrosion at pores in the coating of tinplate. The rates of growth and the constitution of some films have been studied by :—

(*a*) Estimation of combined oxygen by controlled cathodic reduction.

(*b*) Separation of films from the metal for chemical and physical examination.

The combination of these methods has given useful information about the chemical composition and rates of growth of some of the films.

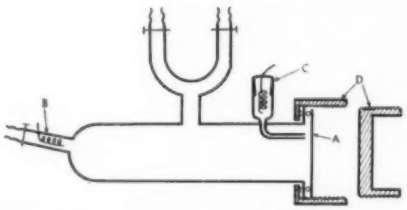
EXPERIMENTAL METHODS

Cathodic Reduction

When an oxide-covered metal is subjected in an electrolyte to a low cathodic current density, the end of oxide reduction is detectable by the change in potential of the metal. If, therefore, the current is constant, uniformly distributed, and wholly used in oxide reduction without evolution of hydrogen, the number of coulombs required to reduce the oxide can be calculated. The method has been extensively investigated for films on copper[1] and iron[2]; its applicability to tin has been pointed out by Salt and Thomas[3], and Katz[4] has used it to obtain indications of the rate of growth of oxide films on tin.

The circuit used was similar to that of previous users of the method; a 200 V. dry battery, a variable high resistance, a micro-ammeter and the electrolysis cell were in series, and the test-piece was connected through a valve voltmeter to a reference electrode. The design of the electrolysis cell and the choice of electrolyte were based on the results of preliminary experiments.

Campbell and Thomas[5] have pointed out that errors may arise from the reduction of oxygen dissolved in the electrolyte; experiments were therefore performed to establish how rigorous an elimination of oxygen was needed for the examination of tin. Measures to diminish the amount of dissolved oxygen improved the sharpness



A. Test specimen; B. Anode; C. Reference electrode; D. Brass specimen holder.

Fig. 1.—Cathodic reduction cell.

of the indication given by the potential/time curves and decreased the apparent amount of oxide indicated. A procedure with a closed cell, which gave results in all respects similar to those obtained with more rigorous methods of oxygen elimination, was as follows :—

(*i*) Boil the electrolyte under atmospheric pressure for 30 minutes and cool under nitrogen.

(*ii*) Evacuate the cell, fill with nitrogen and evacuate again.

(*iii*) Pass the cooled electrolyte into the cell.

The cell was designed to permit these operations to be carried out easily and to provide reproducible satisfactory conditions for oxide reduction; a diagram is shown in Fig. 1. It is a cylindrical glass vessel over one end of which the test specimens are sealed to expose to electrolysis a circular area of diameter 3 cm. The anode is a spiral of platinum wire sealed into the other end of the cell. As reference electrode, a silver wire coated with silver chloride is sealed into a side tube which terminates in a capillary with its tip close to the surface of the test-piece. Other side-tubes fitted with taps permit evacuation and the introduction of the electrolyte. The test pieces were sealed to the flanged end of the cell by a screwed brass assembly packed with rubber O rings.

The electrolyte composition was studied with the objects of avoiding both change in the films before electrolysis began and attack of the film by cathodically-produced alkali during electrolysis. A variety of solutions, with and without buffer capacity, with *p*H values of 3·5–13 was used for the reduction of films produced on tin by oxidation in air. In solutions of *p*H above 9, and in some buffer solutions of lower *p*H, there appeared to be some chemical destruction of the film,

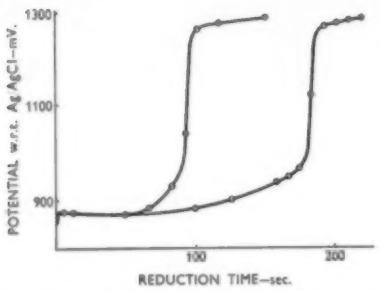


Fig. 2.—Potential/time curves obtained in the cathodic reduction of air-formed films on tin.

and the potential/time curves obtained during the reduction of the thicker films gave an uncertain indication of the end of oxide reduction. Consistent results and the sharpest breaks in the potential/time curves were obtained with solutions buffered to a *p*H of about 7. A solution of 0·01N potassium chloride, buffered with a mixture of sodium dihydrogen phosphate and disodium hydrogen phosphate to *p*H 7·3, gave the best all round results, and was used for the main experiments.

In this solution, current density on the cathode could vary within wide limits without effect on the results. For thinner films, such as those forming in air at ordinary temperatures, a cathode current density of 20 μA./sq. cm. was used, but for thicker films, current densities up to five times this value were employed to reduce the time of experiment and to give more sharply defined end-points. Examples of the potential/time curves obtained during oxide reduction are shown in Fig. 2. Some variations in the form of curve will be referred to later.

Separation of Films from Metal

Dissolution of tin in alcoholic solutions of iodine or in metallic mercury left the surface films apparently unaffected. Of these agents, mercury appeared least likely to cause damage to the film, either during the dissolution of the tin or during the subsequent cleaning of the separated film, and its use was developed.

The films, even the more robust ones formed by heating in air, were extremely fragile, and it was necessary to apply a re-inforcement in order to permit areas large enough for study to be detached. A solution of Formvar in chloroform or trichlorethylene was found generally suitable, and a satisfactory coating was obtained by dipping the specimen into solutions of 0·5–2% concentration. The thicker Formvar layers obtained by the use of the stronger solutions made the detached film much easier to handle, but for most forms of chemical and physical examination, the less Formvar the better. The method of detachment is as follows :—

The metal specimen carrying its film and a coating of Formvar, with the edges trimmed to expose bare tin, is placed in a glass vessel with one edge resting in a pool of mercury. The mercury amalgamates rapidly with the tin and soon rises up the specimen under the surface film. The spread of the attack can be accelerated by reducing the inclination of the specimen to the horizontal, and by gentle rocking of the container. According to circumstances, a film over an area of 60 sq. cm. is undermined sufficiently for removal in 30–60 minutes.

The penetration of mercury is visible through the film. When it appears to have covered the surface, the specimen is withdrawn and one edge of the film is lifted with the point of a needle : the whole film can then be gently peeled from the surface. For films of especial fragility, a small piece of adhesive tape can be applied to one edge and used as a means of holding the film whilst it is detached and transferred to a container. Small drops of mercury may cling to the underside of the film, but are easily removed with a clean soft brush.

The method may be applied either to rolled sheet tin or to tinplate. The quickest and easiest removal is experienced with heavily coated hot-dipped tinplate.

RESULTS

Oxide Films Formed in Air

Verification of Method

In order to check the experimental methods, a special experiment was performed with tinplate. Through the kind co-operation of the Chemical Research Laboratory, D.S.I.R., samples were cathodically cleaned, weighed, heated at 220° C. for 24 hours and re-weighed ; the increases in weight so obtained are the weight of oxygen combined in the film. On part of the surface of several specimens, the combined oxygen was estimated by cathodic reduction ; from the remainder of the surface the film was detached, and its tin content was determined by chemical analysis. Other films formed at 200°, 210° and 220° C. were detached, and after most of the Formvar reinforcement had been dissolved in chloroform, the film fragments remaining were examined by X-ray diffraction. This identified the film material for all the temperatures of oxidation as stannous oxide. The other results of the experiment are shown in Table I.

The two sets of results for the oxygen content of the film are in excellent agreement, giving confidence in the cathodic reduction method. The combination of these results with the values obtained for the tin content of the film provides a strong indication that the composition of the film is mainly stannous oxide, as was indicated by the X-ray examination. This finding is in accordance with the information given by previous investigations[6, 7] of films formed on tin by heating in air and examined by electron diffraction whilst still on the metal. It differs from the finding of Kutzelnigg[8], who obtained stannic reactions from films removed from the metal with ferric chloride solutions. The possibility of a change in the film during chemical stripping cannot be excluded, and the evidence from electron-diffraction, X-ray analysis and the analytical method of the present research provide together strong evidence that the film is stannous.

As judged by colour changes, the thickening of the film on tinplate varied from crystal to crystal of tin. Experiments with specimens with the oxide over part of their surface reduced before measurement suggested that the reduction values give the total oxide on the

TABLE I.—EXAMINATION OF OXIDE FILMS FORMED ON TINPLATE HEATED IN AIR FOR 24 HOURS at 220° C.
(Weights expressed as mg./sq. dm.)

Oxygen Content		Tin Content of Detached Films	Atomic Ratio of Oxygen : Tin (calculated)
By Weight Gain	By Cathodic Reduction		
0·44	0·45	3·16	1·02
0·31	0·29	2·61	0·87
0·43	0·43	3·25	0·97
0·36	0·38	2·61	1·05
	0·33	1·96	1·29
	0·29	2·12	1·09
0·32	0·36		
0·40	0·41		

surface; this is supported by the correspondence between reduction value and weight gain.

Rates of Growth of Films in Air

Specimens of rolled tin (99·99%) were cleaned cathodically in 1% sodium carbonate solution, and then heated in air at several temperatures for various periods. The oxygen content of the films formed was estimated by cathodic reduction, giving the results shown in Fig. 3. At 180° and 210° C., the curve relating oxygen content to time is a parabola. At ordinary temperatures, the relationship is logarithmic, as also found by Katz.[4] The oxide growth on tinplate at 30° C. was studied for both longer and shorter periods than those indicated in Fig. 3. Reduction values (mc./sq. cm.) were obtained as follows :—

2 minutes	1·4
30 minutes	1·5
1 hours	1·6
6 hour	1·7
1 day	1·75
7 days	2·0
28 days	2·1
84 days	2·2
133 days	2·25

In air at 80% relative humidity, the growth rate was about 50% greater than in dry air. On tinplate stored in uncontrolled conditions for three years after cathodic cleaning, the reduction value was 5·6 mc./sq. cm. This value is rather higher than might be expected from the short period growth rate; the probable reason is discussed later.

The rate of oxide growth on tinplate with the surface as produced in manufacture has not been studied systematically, but samples of hot-dipped tinplate of known age required, for the reduction of their oxide, quantities of electricity (mc./sq. cm.) as follows :—

1 year	3
2 years	4
3 years	5
7 years	6
20 years	6–7

If it is assumed that the films are stannous oxide, the density of the film is similar to that of stannous oxide in bulk, the thickness of film requiring 1 mc./sq. cm. for its reduction is 10·9Å. The measurements indicate on this basis that the thickness of the film formed at ordinary temperatures in days or weeks is about 20Å, and perhaps 50Å after dry storage for about three years. Such thicknesses must be much less than those of the films producing yellow discoloration which has occasionally been reported to occur in long storage. (Colour was observed in the films produced at 210° C., when the estimated film thickness was about 200Å.) Possibly the assumptions of composition and density of films are incorrect, but it is probable that the growth of films is influenced by atmospheric conditions other than temperature and humidity. Kenworthy[9] found the gain in weight of tin specimens hanging in a laboratory with some shelter from dust to be linear with time over a period of two years, and observed discoloration of the metal after 150 days. Evidently the logarithmic growth curve obtained in the present research applies only to clean dry air. A similar difference for film growth on zinc has been observed[10] between specimens in freely circulating indoor air and those exposed to controlled conditions in closed vessels. There seems little doubt that acidic atmospheric impurities modify the nature of the film on the metal, and hence its rate of growth. The

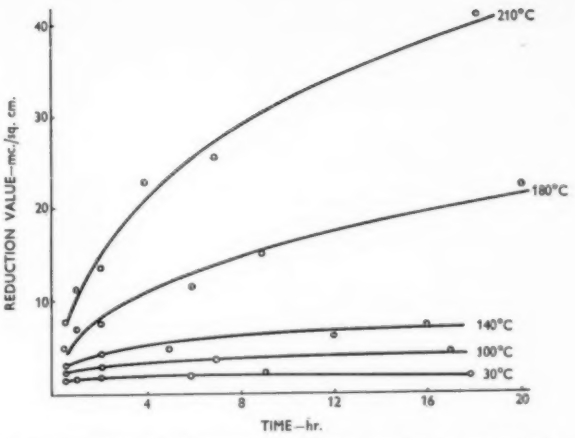


Fig. 3.—Relation between reduction value of oxide and time of oxidation for tin heated in air.

film growth on the tinplate samples stored in clean dry cupboards was somewhat faster than that indicated by the experiments in desiccator vessels, and could no doubt be faster still in poorer conditions of storage, reaching at worst the linear relation of film thickness with time observed by Kenworthy.

Examination of detached films by electron microscopy is being carried out under the direction of Professor J. J. Trillat and results will be presented in detail elsewhere. Confirmation has been obtained that the films formed by heating in air above 170° C. are stannous oxide. The films formed at lower temperatures have not given diffraction patterns and are apparently amorphous. Previous examinations by electron diffraction of films in position on the metal have given no detectable pattern from films formed below about 190° C.[6] or 130° C.[8], but have shown the stannous oxide pattern from films formed at higher temperatures. The present investigation with detached films permits examination by transmission, and should therefore offer a better chance of obtaining a definite result for the thinner films. All investigations point to a change in the structure of the film as its temperature of formation is raised; this finding is consistent with the thickness/time relationships observed. At the higher temperatures, the parabolic growth curve is appropriate to the crystalline film with migration through the lattice but, at the lower temperatures, the growth of the amorphous film could well follow a logarithmic law dependent on the random occurrence of fissures.

Effect of Alloying Elements in Tin

It is known that small additions of phosphorus, indium or zinc to tin prevent the formation of coloured films when the metal is heated. The cathodic reduction method was applied to the study of the growth of films on tin containing 0·1% of one of these three elements.

For the zinc-containing tin, satisfactory potential/time curves could not be obtained, possibly because zinc entered the oxide film in considerable amounts.

When indium was added, a potential/time curve showing two steps was obtained, a larger one corresponding to reduction of the tin oxide, and a smaller one at a more negative potential with uncertain significance.

When phosphorus was present in the tin, clear-cut single-stepped potential/time curves were obtained.

A considerable reduction in the oxidation rate of tin on heating in air was indicated as a consequence of the addition of phosphorus or indium. The reduction values obtained for metal heated at 210° C for 18 hours were as follows :—

Pure tin	42 mc./sq. cm.	
Tin with 0·1% phosphorus ..	9·2 mc./sq. cm.	
Tin with 0·1% indium	8·2 mc./sq. cm.	(tin oxide reduction only)
Tin with 0·1% indium	14·4 mc./sq. cm.	(complete reduction)

Films Formed by Passivation Treatments

Three types of passivation treatment have been examined, as follows :—

(1) The Protecta-tin process—immersion in a solution containing 10g./l. caustic soda and 3g./l. sodium chromate at 90° C.

(2) Immersion in 1% chromic acid solution at 85° C.

(3) Cathodic/anodic treatment in 2% potassium dichromate solution at room temperature. Cathodic treatment at 12 A./sq. ft. for 10 seconds was followed by anodic treatment at 1 A./sq. ft.

The processes were applied to hot-dipped tinplate, to electrolytic tinplate, and to rolled tin, all cleaned cathodically at 10 A./sq. ft. in 1% sodium carbonate solutions beforehand. For the Protecta-tin process, which is unsuccessful on a freshly reduced surface, the samples were allowed to oxidise in dry air for seven days before treatment, but for the other processes, treatment followed immediately after cleaning.

The potential/time curves obtained during the controlled reduction of the films differed somewhat for the three materials. For electrolytic tinplate, the single stepped reduction curve similar to that obtained during the reduction of air-formed films was always obtained. For hot-dipped tinplate and rolled tin, the arrest in the curve corresponding to the reduction of the tin oxide was obtained, but usually a second step or an inflexion was observed at a more negative potential as the reduction was continued. Bouillon, Piron and De Lil[11] have found more than one step in the reduction curves of cuprous hydroxide films on copper. These seem to be characteristic of the electrolyte, and in the present research some complex curves were observed when unbuffered electrolytes were used. The effect now mentioned, with its dependence on the basis metal, is apparently rather different, and its significance will be discussed later.

The Protecta-Tin Process

The presence of a protective film formed by the Protecta-tin process can be demonstrated by an immersion of the metal in a hot potassium polysulphide solution, which stains unprotected tin. This test was used to assess the extent of removal of the film during cathodic reduction. It was found that when reduction was stopped immediately after an indication had been obtained from the potential/time curve that reduction of tin oxide was complete, the tin surface still had some resistance to the sulphide solution. A detectable but declining resistance to the sulphide solution was observed if reduction were carried to the beginning of hydrogen evolution, and was only lost when hydrogen evolution at increased current density was permitted to occur for some minutes. The intermediate step or inflexion observed between the potential for tin oxide reduction and the final potential of hydrogen evolution did not correspond to any change in the resistance of the surface to the sulphide solution. Probably, therefore, the second step does not represent the reduction of a particular film constituent, but represents a stage in hydrogen evolution, possibly connected with the presence of specially active spots or trace impurities. The difference in behaviour of rolled tin, hot-dipped tinplate and electrolytic tinplate indicates that the composition or surface condition of the metal is concerned in the effect.

The persistence of some protection of the tin surface after the presumed reduction of the tin oxide suggests the presence in the film material of some compound not reduced at a potential less negative than that of hydrogen evolution. The film was detached from 2,000 sq. cm. samples of tinplate after treatment in the passivating solution ; analysis of the detached films showed the presence of chromium to the amounts expressed as Cr_2O_3 in mg. $\times 10^{-4}$/sq. cm., as follows :—

Hot dipped tinplate (10 seconds treatment) ..	5·8
Hot dipped tinplate (10 minutes treatment) ..	7·3
Electrolytic tinplate (10 seconds treatment) ..	7·4

For the same materials and treatments, the cathodic reduction results suggest tin contents of all three films equivalent to $2{\cdot}8 \times 10^{-4}$ mg./sq. cm. of SnO. No attempt at chemical estimation of the tin was made, since insufficient confidence was felt in the freedom of the detached films from tin-contaminated mercury ; the extreme fragility of these thin films forbade a rigorous cleaning treatment.

The cathodic reduction value of the tin oxide content of the film, 0·6 mc./sq. cm., is considerably less than that for the air-formed film already present on the tinplate before immersion in the treatment solution (2 mc./sq. cm.). There was no detectable change in the protective quality of the film with periods of passivation treatment over five seconds, and it is probable that the film does not change substantially after the first few seconds.

It seems likely that the film consists of either mixed chromium or tin oxides, or a compound with a molecular ratio of chromium to tin oxide of about 2 : 1. Examination of detached films by electron diffraction has not so far yielded identifiable patterns.

When tinplate passivated by the Protecta-tin process was heated in air, cathodic reduction produced potential/time curves of insufficient regularity to make a precise estimation of the rate of film growth possible. It could be shown, however, that the rate of growth was much less than that found with untreated tinplate, and that the partly protective constituent of the film remaining after presumed reduction of the tin oxide was still present after heating.

Immersion in Chromic Acid

The cathodic reduction curves obtained from samples passivated in chromic acid sometimes had a second step or inflexion after the apparent end of the reduction of tin oxide, but this was less evident than with samples treated by the Protecta-tin process.

The reduction values obtained from consideration of the first step in the curves increased with passivation time, rapidly during the first few minutes and subsequently at a continually diminishing rate, which was, however, still measurable up to 60 minutes treatment time (Fig. 4). The protective value of the film formed,

as judged by resistance to growth during heating in air, was not changed substantially by increased treatment time. A great part of the protective quality of the film was retained after apparent reduction of the tin oxide component, and, as with the Protecta-tin process, this persisted until hydrogen evolution had been allowed for some minutes.

Chemical analysis of detached films showed the presence of chromium to an extent equivalent to $1 \cdot 1 \times 10^{-4}$ mg./sq. cm. of Cr_2O_3. The same value was obtained for treatment times of 10 seconds and 30 seconds, but the tin content as assessed by cathodic reduction was, for these treatment times, equivalent to $8 \cdot 5 \times 10^{-4}$ and $10 \cdot 6 \times 10^{-4}$ mg./sq. cm. of SnO, respectively. Probably, although the tin oxide continues to grow in thickness, the chromium content of the film remains fairly constant, but it is this content that confers most of the protective quality on the film.

Cathodic/Anodic Treatment in Potassium Dichromate Solution

The development of second steps in the cathodic reduction curves was well marked, but with specimens treated for up to 10 seconds by the anodic process, a clear indication of tin oxide reduction was obtained. This suggested a rapid rate of film growth in the first few seconds. The cathodic reduction curves for specimens treated anodically for 10 seconds or more were difficult to interpret, and a dark deposit was left on the surface after reduction. For anodic treatment times exceeding 30 seconds, the film formed was visibly lacking in adhesion ; possibly the formation of a loose outer layer caused the irregularity in cathodic reduction of the thicker films. The protective quality of the films, as judged by the growth on heating in air, changed little with time of treatment, and, as for the other passivation films, a substantial part of the protective quality was retained after reduction up to the point of prolonged hydrogen evolution.

Chemical analysis of detached films for chromium, and cathodic reduction measurement for tin, gave results as follows, expressed in mg. $\times 10^{-4}$/sq. cm.

	Chromium (as Cr_2O_3)	Tin (as SnO)
1 second anodic treatment ..	19·2	6·3
3 second anodic treatment ..	22·1	10·5

The content of chromium is therefore appreciably greater in these films than in the others examined, but increases much less rapidly with time of treatment than the tin component.

Film Growth in Distilled Water

The immersion of tin in hot distilled water produces a coloured film in a few hours, an effect familiar in the hot-water test for the porosity of coatings. Cathodic reduction values of the films formed during immersion of tin in boiling distilled water for various periods, together with results for films formed by heating in dry air at 100° C., are shown in Table II.

TABLE II.—GROWTH OF FILMS AT 100° C. IN AIR AND DISTILLED WATER.

Time of Treatment (min.)	Reduction values (mc./sq. cm.)	
	Boiling Distilled Water	Dry Air
5	1·9	—
30	2·45	2·5
60	3·4	2·7
130	4·05	3·1
240	4·5	3·3

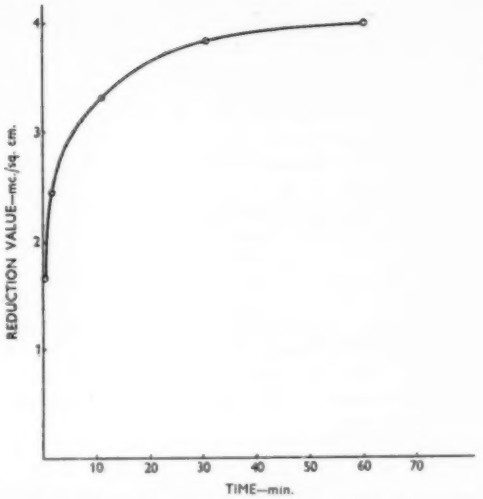


Fig. 4.—Relation between reduction value of oxide and time of treatment for tin immersed in 1% chromic acid at 85° C.

The reduction values increase somewhat more rapidly for the wet conditions, but the reduction value at which a yellow colour was produced was only 4·5 mc./sq. cm., about a quarter of the value found for yellow air-formed films. From the evidence of colour change and of some differences in behaviour, the films formed in water and in air differ in constitution, in thickness, or in both ; the cathodic reduction value gives an inadequate guide to the extent of such differences.

DISCUSSION

The comparison of the results obtained by cathodic reduction with the gains in weight on oxidation gave confidence that the reduction method is well suited to study of the growth of oxide films on tin in air. The similar reduction curves obtained for films formed in other ways suggests that the method is also applicable to study of their growth, and could be used, for example, to help the control of film thickness in the chemical treatment of electrolytic tinplate on the production lines.

The method gives, however, no indication of the composition of the films on the metal, either in respect of their oxidation state or degree of hydration. The oxidation/reduction potentials of stannic and stannous oxide lie within a few millivolts of one another[12], and no indication of separate reduction steps for the two oxides was expected or obtained in the experiments. Without knowledge of the composition of the films, it is not possible to estimate their thickness in terms of linear units. More important, the constitution of the films could exercise as great an influence on their behaviour as their thickness. For example, the probably hydrated films formed by boiling tinplate in distilled water differ in appearance and behaviour from films of similar reduction value formed in air. Moreover, the layers formed on tinplate covered with an oil layer may include compounds other than oxides or hydroxides, with an accompanying influence on behaviour, especially in respect of lacquer adhesion. The cathodic reduction method has given no evidence on this matter.

The films formed by passivation in chromate-contain-

ing solutions are difficult to assess completely by cathodic reduction. It has been shown that chromium enters into the film substance and makes a large contribution to its performance. The cathodic reduction method, which gives no indication of the chromium content of the films, does not therefore offer a direct means of assessing the protective quality of the passivation films. However, in all of the three processes studied, the chromium content shows little change with time of treatment, whereas in two of them—immersion in chromic acid and cathodic/anodic treatment in potassium dichromate—the cathodic reduction value increases with time of treatment. This value may therefore be used to assess film thickness, which may have effects on lacquer adhesion, even though it may not much affect protective value. The method would probably be unsuitable to compare the films produced by different processes, but should be satisfactory as a production-line check on the film produced by any one process.

Although the methods used have not provided means of revealing all that could be desired about films, much useful information has been obtained. This may be increased if examination of detached films by physical means is fruitful. Meanwhile the conclusions reached may be summarised.

CONCLUSIONS

(1) The controlled cathodic reduction, in air-free buffered solutions, of oxidised tin enables an estimate to be made of the amount of oxygen combined with tin in the surface film.

(2) Films may be detached from oxidised tin by dissolving the underlying metal in mercury in order to provide specimens suitable for chemical and physical examination.

(3) The oxide formed on tin heated in air at 200°–220° C. is stannous oxide. At temperatures below 180° C. the composition is uncertain and the films may be amorphous.

(4) The films formed by treatment of tin in acid or alkaline chromate solutions contain chromium, and largely depend on this for their protective quality.

(5) Although the amount of chromium in the passivation films could not be assessed by cathodic reduction, chemical analysis of detached films suggests that it changes little with time of treatment by any one process, but that it differs from process to process. The component of the passivation films measurable by cathodic reduction, presumed to be tin oxide, increases with time of treatment for immersion in chromic acid, or by cathodic/anodic process in dichromate. Cathodic reduction may therefore be used on a production-line check on the film thickness produced by chemical treatment of electrolytic tinplate.

(6) For immersion in alkaline chromate solution (Protecta-tin process), the tin component of the film does not vary with time of treatment over three to five seconds, and its reduction value is much less than that of the air-formed film present on the metal before treatment.

(7) The amount of oxide forming on tin in clean dry air at 30° C. varies with the logarithm of the time of storage. The relation between thickness and time changes as the temperature is increased, and at temperatures over 180° C. the thickness of oxide varies linearly with the square-root of the time of storage.

(8) The rate of growth of oxide is higher in moist air than in dry air, but declines with time in the same way. The linear relation between the film weight and time at ordinary temperatures reported previously is ascribed to the influence of atmospheric impurities.

(9) The addition of 0·1% of indium or phosphorus to tin much reduces the rate of oxidation in air.

ACKNOWLEDGMENTS

The work described was carried out at the Tin Research Institute, and the authors are indebted to the International Tin Research Council for permission to publish their results, and to their colleagues, Dr. J. W. Price and Mr. R. F. Smart, for chemical and X-ray examinations, respectively, of detached films.

The help given by the Corrosion Group of the Chemical Research Laboratory, D.S.I.R., under Dr. F. Wormwell, in carrying out the controlled oxidation and weighing of a number of samples was also much valued.

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Gallium Production in Hungary

DR. JÓZSEF UVEGES, of the Hungarian Metal Research Institute, has given some details to the newspaper *Esti Hirlap* (Evening Herald) of his work with Dr. Elemer Papp, a department head of the institute, to produce the rare metal gallium from sodium lye, used in the aluminium industry. Their research began in 1954, when gallium was found in the lye used in processing bauxite into alumina. After two years of experiments they succeeded in mid-1956—for the first time in Hungary—in extracting a small quantity of the pure metal. Experiments were continued in larger laboratories and they had now produced 30 g. of gallium. A kilogram of the metal could be obtained from every 10 cu. m. of lye from the alumina factories, and the next step would be to set up an experimental factory. The process is not expensive: the energy required is about half that needed to make the same quantity of aluminium. Washing soda is a by-product of the process.

Argonaut Welding Wire Approval

BRITISH OXYGEN GASES, LTD., announce that the Admiralty has approved the following wire for the Argonaut process—A. 675 welding wire in diameters 0·045 in., $\frac{1}{16}$ in., and $\frac{3}{32}$ in., for the welding of mild steel in the flat position. The wire has also been approved for the fillet welding of mild steel in the horizontal-vertical position.

CO-OPERATIVE RESEARCH

Survey of the Activities of the Research Associations

B.C.I.R.A. B.I.S.R.A. B.N.F.M.R.A.
B.S.C.R.A. B.W.R.A.

The British Iron and Steel Research Association

The processes involved in the manufacture of iron and steel are carried out on a large scale, and, particularly since the war, the aim has been to increase the output of the industry as a whole, both by laying down more plant and by improving the efficiency of existing plants. In the success which has been achieved in the latter objective, the Association has played an important part in developing improved methods and new techniques. Some aspects of B.I.S.R.A.'s work for makers and users of iron and steel are considered here.

THE work of the British Iron and Steel Research Association is organised in five divisions—Ironmaking, Steelmaking, Mechanical Working, Plant Engineering and Metallurgy (General)—and three departments—Chemistry, Physics and Operational Research. The laboratories are situated in London, Sheffield, the North-East Coast and Swansea, the last two being mainly concerned with ironmaking and sheet and strip and its coating, respectively. In the following survey, examples have been selected to illustrate the type of investigation undertaken in these various fields.

Ironmaking

Statistical Analysis of Blast-Furnace Data

For many years attempts have been made to establish some correlation between the many factors that affect the performance of a blast furnace. The aims of such studies are various: they would provide standards by which the performance of a furnace could be assessed in relation to conditions prevailing at a particular time; they would help in predicting the effects of changes in raw materials, burden preparation, and operating techniques; and they might help in making comparisons between the performances of furnaces of different sizes and designs.

The factors that affect the performance of a blast furnace are many, and the "classical" method of studying such a problem would be to carry out experiments in which the effects of changes in one variable were studied while all other variable factors were kept constant. It is extremely difficult, if not impossible, to carry out experiments of this kind on an operating blast furnace. Fortunately there is another way: the methods of mathematical statistics can be applied to collections of routine operating data to discover whether any correlations exist. This has been done by the Ironmaking Division of B.I.S.R.A. Weekly figures for seven furnaces for periods of from one-and-a-half to six years were analysed, taking into account about twenty or thirty factors for each (most of these factors were subsequently found to be irrelevant). The statistical work took the form of multiple regression analysis. This consists essentially of expressing one variable, called the dependent variable, as a mathematical function of several independent variables. In this investigation the main dependent variables examined were the fuel consumption per ton of iron, the fuel input, and the amounts of iron produced. The result of a regression analysis is expressed as a set of multiple regression equations. Each of these equations shows what effects the various factors represented by independent variables have on one of the dependent variables, for example, fuel consumption.

Although regression analysis is fundamentally a simple procedure, the volume of the calculations entailed in an analysis of this kind is far beyond the resources of desk calculating machines. Most of the work in this investigation was carried out on the electronic computer at the University of Manchester, using a detailed program* specially prepared for this purpose.

The main variables used were:

Coke Quality: Either the proportion of fixed carbon or the proportion of sulphur was used as an independent variable. Physical properties or, in their absence, the proportion of bought coke were also included.

Burden: Either the total weight of burden per ton of iron produced or the slag volume was used as an index of the richness of the burden. The physical characteristics and reducibility of the constituents of the burden were also taken into account.

Product Variables: The silicon content of the iron and the basicity of the slag are examples of variables in this group.

Driving Index: Weekly consumption of coke or carbon was used in preference to blast volume, which is not always known so accurately.

Operating Variables: These included temperature and humidity of the blast, and time off blast.

* This is the spelling advocated by the British Standards Institution in this context.

Fig. 1.—B.I.S.R.A. suction pyrometer complete with venturi and ejector. The refractory shield can be seen inside the water-cooled probe.

The variables selected—they are not the same for each regression equation—were carefully chosen to avoid including pairs having a high mutual correlation, for it is essential that no two variables in a regression equation should be so closely related that they vary together. Thus, either the total weight of the burden or the slag volume per ton of iron was used as a measure of the amount of iron charged, but not both. Blast-furnace operators gave advice on the problem of selecting variables.

The regression equations are tabulated in full in the original paper. The salient features of the analysis are as follows :

(*a*) An increase of 1 cwt./ton in total burden results in an increase of 0·15 cwt./ton in carbon rate.

(*b*) An increase of 0·1 unit in CaO/SiO_2 in the slag results in an increase of 0·35 cwt./ton in carbon rate.

(*c*) An increase of 100° C. in blast temperature results in a decrease of 0·4 cwt./ton in carbon rate.

(*d*) An increase of 10% hard ore (at the expense of soft ores) results in an increase of 0·4 cwt./ton in carbon rate.

(*e*) An increase of 10% sinter results in a decrease of 0·7 cwt./ton in carbon rate.

(*f*) An increase of 1% silicon in the metal results in an increase of 1·2 cwt./ton in carbon rate.

(*g*) In each case there is a proviso that all other variables remain unchanged.

These facts should be of practical value to blast-furnace operators. No similar account can yet be given for the factors influencing carbon consumption and iron make.

Steelmaking

Developments in Suction Pyrometry

A suction pyrometer of new design (Fig. 1) has been developed to meet the need for a robust instrument that would measure air preheat temperatures accurately over long periods and be easy to maintain. The special feature of the pyrometer is that the refractory radiation shield is surrounded by the water-jacket necessary for any pyrometer used in an open-hearth uptake. This arrangement has several important advantages :

(1) The shield is protected from the furnace gases when their temperature is not being measured.

(2) The temperature of the shield and thermocouple is never greater than that of the air in the uptake.

(3) It is not necessary to take precautions against spalling.

(4) The accuracy of the instrument is made independent of the temperature of the uptake walls, because the thermocouple and shield are surrounded by a water-jacket maintained at a constant temperature.

The shield system which protects the thermocouple from radiation loss to the water-jacket was developed jointly by B.I.S.R.A. and Land Pyrometers, Ltd., and consists of three concentric sillimanite tubes with ribs between them. This arrangement proved more reliable than earlier designs, and has now become accepted practice for measuring air temperatures from 1,000°–1,400° C. The patent application taken out by B.I.S.R.A. (No. 21124/54) has been assigned to Messrs. Land Pyrometers, Ltd.

The accuracy of this instrument has been established in works tests. For a given gas velocity and temperature the error remains constant for a considerable time, and only becomes serious when two or more openings in the refractory shield are completely blocked. In one trial, for example, the temperature at the start was 1,100° C., the error being about 15° C. After the instrument had operated unattended for three days in an open-hearth uptake, the error had increased to 25° C. at 1,100° C.

The refractory shield or the thermocouple sheath can be replaced in a few minutes without removing the thermocouple from the water-jacket. The life of a shield under average conditions and with no special precautions is usually two heats. This can be lengthened considerably by suitable methods of operation and by careful selection of sampling points.

Metal Working

Width Meter for Wide Strip

In the absence of a method of adequately measuring the width of hot steel strip during rolling, a considerable amount of material is inevitably wasted, since it is not possible to roll a precise width. B.I.S.R.A.'s Physics Department has developed a width meter for this purpose.

The B.I.S.R.A. system* makes use of the infra-red radiation emitted by the hot strip to detect the position of its edges. The diagram (Fig. 2) shows the principle of the system. Mounted vertically above the edges of the strip are two " follower units," each of which is used to measure accurately the position of one edge. Each follower unit is arranged so that an image of the strip edge in infra-red light is focused on a photocell. If the edge moves to one side or the other, the amount of light falling on the photocell changes : the resulting signal from the cell is amplified and used to control a shutter, which is moved across until all except a narrow band at the edge of the strip is obscured. The shutter thus " follows " the movements of the strip edge as the width of the strip varies.

Obviously, variations in the temperature of the strip or in the sensitivity of the photocell will affect readings. Temperature errors are counteracted by balancing the

* British Patent Application 27651/54.

radiation received by the cell in each follower unit against the radiation received by an identical photocell from a constant small area of strip a short distance in from the edge. The use of infra-red radiation has the advantage that the readings obtained are unlikely to be affected by variations in the illumination of the strip by visible light.

The instrument indicates the width of the strip with an accuracy better than $\pm \frac{1}{16}$ in. over a range of 6 in. (i.e. 3 in. above and below the nominal width). The delay in registering a change in the width of the strip is less than 0·15 sec.

Position Control for Screwdown Drives

Screwdown drives for rolling mills are usually operated from the pulpit by a multiple controller, each step of which corresponds to a given speed of the screwdown motor. A control system of this sort, although it is simple, requires considerable skill on the part of the operator, and demands his attention throughout each movement. He has to operate a control to switch on the screwdown motors, wait until the rolls have nearly reached the position required, as indicated by the screwdown dial, and then judge the right moment to switch off again.

With position control, once the roll setting is chosen, the rolls are automatically brought to that setting and the screwdown motors switched off at the right moment without any further action by the operator. Position control of screwdown offers two main advantages: greater accuracy and quicker operation. Both the accuracy and the speed of the control systems now in use are limited by the skill and fatigue of the human operator, but a position control system performing the same operations will maintain a high and constant standard throughout the working shift. With conventional controls, more than half the total time spent in rolling an ingot is taken up in operating the auxiliary drives; position control can reduce this substantially. Position control also offers the prospect of using fewer operators and of reducing the time required to train them. In addition, more exact control, with the consequent reduction of "inching" and over-shooting, should reduce maintenance on the motors.

Position control has been applied to rolling mills in two forms, which are known as "follow-up" and "pre-set" control. In the first of these two systems, the screwdown "follows-up" each movement of the operator's control lever. In "pre-set" control the sequence is set in advance and each movement of the rolls is initiated by the operator when required. This method of control is more suitable where a pre-arranged schedule has to be followed closely; thus, long rolling pass sequences can be handled quickly and accurately by pre-set programme control. It is claimed by its advocates that pre-set control not only makes it possible to increase production, but also gives better and more uniform quality, because the rolling schedule can be set by a highly skilled person.

"Follow-up" position control is suitable where flexibility is more important than speed, and where schedules are not rigidly fixed. Alterations to meet abnormal conditions, such as variations in the temperature of the ingots, can be made by an over-riding manual control.

Electrical position control systems can use either limit switches, potential dividers, or synchro elements. All three methods of control use some form of feed-back so that the control circuit is a closed loop, an error signal from the screwdown motor being fed back to the control.

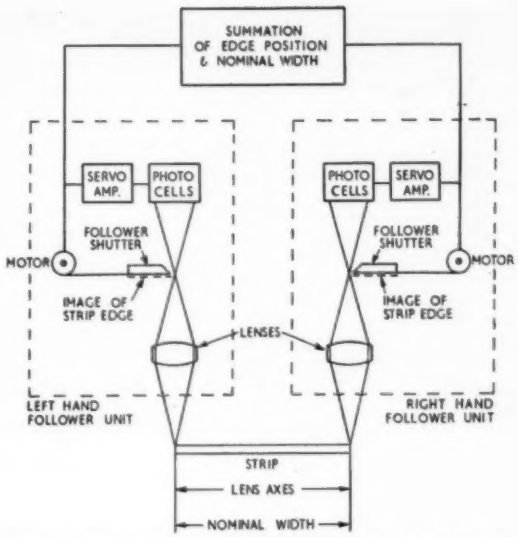


Fig. 2.—Schematic diagram of the B.I.S.R.A. width meter, showing how the signals from the follower units are combined to give the width of the strip.

Metal Coatings

P.V.C.-on-Steel Laminate

There are many potential uses for a new laminated material consisting of a thin film of P.V.C. (polyvinyl chloride) bonded to steel sheet or strip. This laminate combines many of the advantages of both the materials of which it is composed; its surface resists abrasion, the weather, and chemical attack, and has an attractive appearance. The laminate can, moreover, be subjected to metal-working processes such as bending, deep-drawing, and roller-forming without harming the plastic film. The steel backing gives the laminate strength and ductility at low cost.

The decorative and durable surface of this laminate makes it suitable for consumer goods of many kinds; table tops, wall panelling, office furniture, radio and television cabinets, cases for electrical switchgear, fittings for motor cars, industrial roofing, and tanks for chemicals are among the many uses that have already been found for it.

A pilot line for continuously laminating strip up to 3 in. wide is now operating at the Association's South Wales Coatings Laboratories at Swansea (Fig. 3). The laminating process developed by B.I.S.R.A. (for which a patent has been applied) produces a material with properties which, for several uses, are superior to those of the American product. The plastic film is so firmly bonded to the steel that it is scarcely possible to peel them apart without breaking the film. The results of "peel strength" tests obviously depend on the qualities of the plastic film, but values of up to 30 lb./in. have been obtained with films about 0·01 in. thick. Samples of the laminate made by the B.I.S.R.A. process, which is to be called Plasteel, have been successfully bent, sheared, lock-seamed, roller-formed into sections, and deep-drawn into cups $1\frac{3}{8}$ in. in diameter without

Fig. 3.—Pilot line for laminating steel strip with plastics at B.I.S.R.A.'s Swansea Laboratories.

causing any damage to the coating. In all tests the limit of formability of the product has been set by the properties of the deep-drawing steel.

An apparently unique property of Plasteel is that cups drawn from the laminate can be immersed in boiling water for an hour or more without failure of the adhesion occurring anywhere on the cup. When a similar test was applied to drawn cups made from all the other laminates that were examined, considerable peeling of the plastic film occurred after only a few minutes. A cup of Plasteel will even withstand immersion in glycerine at 200° C. for a few minutes without any failure of adhesion taking place, although there is some darkening of the plastic owing to its partial decomposition at this high temperature. This unique property of Plasteel will be particularly important in certain applications of P.V.C.-on-steel laminate, such as in office and domestic furniture, where the laminated surface may be accidentally exposed to heating appliances or open fires, and in its use as a roofing material, where there can be considerable heating by exposure to the sun's rays.

Fig. 3 shows the arrangement of the pilot line installed in the Association's Laboratories at Swansea. After a preliminary treatment, which may, if desired, include phosphating and chromating, the strip is given a thin coating of adhesive. A hot air drier then removes the solvent and heaters raise the temperature of the strip to cure the adhesive. The heated strip with adhesive on it is then passed between two applicator rolls, where the plastic film is rolled on to it to form the laminate.

Roller Coating of Tinplate

A theoretical study of the nip-roll system for coating weight control resulted in a proposal to apply tin to a steel strip by a roller coater. The speed of the roller relative to the strip then controls the weight of the coating applied. An experimental continuous strip-coating line using the principle has been built. Surface preparation and "fluxing" by electrically heating the strip in a hydrogen/nitrogen atmosphere and tinning under the gas cover has been adopted to avoid using any corrosive fluxes (see Fig. 4). High-lustre coatings of good quality of 8 oz. per basis box thickness and more have been applied on this line at speeds up to 50 ft./min. For a fixed strip speed there is a proportional relationship between the weight of the coating and the speed of the coating roller. Good coatings of lead-tin alloy have also been applied by this process, and several thousand feet of strip have been coated.

The process is a very promising one for tinplate production, because it offers an opportunity of hot tinning at the end of a continuous strip-annealing line, so combining the two processes with resultant economy in processing cost. Furthermore, it may be possible to apply other coatings, such as zinc and aluminium, by roller coating. For these reasons it was decided to develop the process further, and a 12-in. wide strip-processing plant has recently been built. It includes a trichlorethylene vapour-degreasing unit and a strip heating furnace in which the strip is heated directly by passing a current through it. The furnace has three vertical sections; each guide roll is equipped with slip rings and a brush assembly so that current can be passed into the strip as it moves through the furnace, to obtain the required temperature distribution along its length. At the end of the furnace is the tinning unit, with its pair of separately driven coating rollers dipping in their tin baths, so providing for the application of differential coatings. Immediately after the tinning box the strip is quenched in water or oil; the quench tank also provides the necessary gas seal. The strip is drawn through the line by bridle drive units located before the furnace entry and after the quench tank. These units are powered by D.C. motors fed from a Ward-Leonard generator system, so as to give a wide range of strip speed control. A "dancing roll" immediately before the furnace entry measures the strip tension, and the signal from it is used to control automatically the relative speeds of the bridle drives in order to maintain the required uniform tension in the strip in the furnace. Coilers and decoilers are provided at the ends of the line. The furnace gas is provided by a cracked-ammonia generator. The line is designed for speeds of up to 1,250 ft./min., and is equipped with all the necessary instruments for observing and controlling its operation. These include strip temperature pyrometers, strip and coating roller speed indicators, meters for gas pressure at various parts of the furnace and for gas-flow rate. A paramagnetic oxygen meter continuously samples

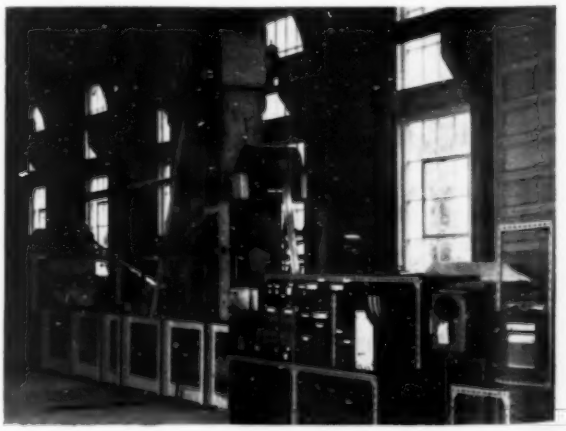


Fig. 4.—Pilot line at Swansea Laboratories for tinning strip 12 in. wide by roller-coating.

the furnace gas and indicates its oxygen content. This monitors the purging process and reveals any significant increase in oxygen resulting from leakage or other cause during operation. The line is now being put into service and tinning experiments should commence shortly.

As this process involves heating the strip to a temperature of about 750° C. in the reducing atmosphere before tinning, temper-rolling usually employed to induce the required mechanical properties in the tinplate will have to be done either under a reducing atmosphere immediately before tinning or after coating. The first alternative is preferred, and an investigation has therefore begun into the mechanism of temper-rolling, with the object of guiding the design of a temper mill or an equivalent process which could be operated under the conditions required.

Continuous Lacquering of Steel Strip

Studies of the function of the tin coating in protecting the interior of a food can, carried out in this laboratory and elsewhere, have demonstrated that for packs other than acid fruits lacquered steel should be suitable. This was confirmed by some wartime experience of packing foods in lacquered steel cans when tin was short. The disadvantages of such lacquered blackplate for can making are that it has no tinned surface for soldering, it cannot be universally used for all food packs like lacquered tinplate, and the lacquers are readily damaged in handling. These difficulties have discouraged development, but new techniques have now been found for tinning the edges for soldering body seams, or lacquering one side of a sheet and tinning the other. The availability of epoxy-phenolic resin lacquers, which are extremely ductile, adhere to steel, and are chemically resistant, and the growing demand for lacquered tinplate in coil form, have further encouraged investigation of strip lacquering practice.

An experimental strip-lacquering line has been built. The arrangement is illustrated in Fig. 5, and consists of a vapour degreasing stage, a differential-speed type roller coater, and a lacquer curing furnace in which the strip can be heated up to 350° C. by passing an electric current through it. Coatings of epoxy resins from less than 0·1 mil. up to 0·5 mil. thick have been applied. The curing times used have ranged from 20 sec. upwards. The work has shown that steel can be protected with a coating as little as 0·15 mil. thick. A method has been found for almost completely eliminating the longitudinal ridging which forms on a roller-coated lacquer surface. This makes it possible to cure the applied lacquer rapidly without having to allow time for the ridging to flow out. It has also been found that, with the lacquers employed, the coating ductility is at its best with curing times of 1 min. or more.

Identification of Differentially Coated Tinplate

Tinplate with a thicker coating of tin on one side than the other is used for can making in the U.S.A., and is expected to come into use here. By this means a 4-oz. coating can be used on the outside of a can, which is adequate protection, and a 16-oz. coating used on the inside to give the protection required for some packs, e.g. acid fruits. As both surfaces are normally lustrous there would be a possibility of confusion in the can-making plants unless one side were marked in some way. Some marking processes in which one face is dulled are used in the U.S.A., but none is completely satisfactory.

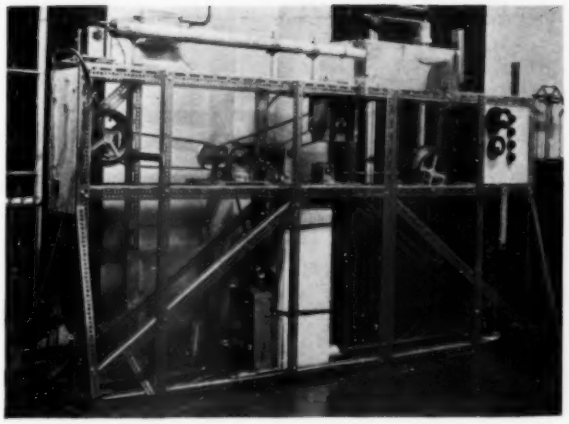


Fig. 5.—Experimental line at Swansea Laboratories for continuously lacquering steel strip.

A new process being developed at Swansea promises to be superior to any so far used. A thin electro-deposit of iron about 0·25 micro-in. thick is applied to one face after tinning but before flow brightening. It has the effect of dulling that side, so as to identify it. The marked surface has a corrosion resistance equal to that of tinplate, can be soldered and takes lacquer well, apparently better than a pure tin surface. This new method of marking is being assessed by the Metal Box Co. Ltd., and is the subject of a joint patent application with the Steel Co. of Wales, Ltd.

Engineering

Crane Tests

During the past five years the Civil Engineering Section of B.I.S.R.A.'s Plant Engineering Division has been carrying out structural tests under operational conditions in iron and steel works on all types of steelworks cranes. The cranes tested included cranes for grabbing, box-charging and ingot stripping, and for handling ladles, ingots, forgings, plates, etc.; their lifted loads ranged from 5 to 325 tons. Individual reports on these tests have been issued as each test has been completed, and a comprehensive report has now been prepared for publication. The report will provide designers with detailed information on the loading imposed on cranes during all phases of their use, and guidance on methods of calculation and permissible stresses, which will eliminate the effects of fatigue arising from the arduous working conditions to which steelworks cranes are subjected. The research has also made it possible to introduce the idea of graded permissible stresses, and the Plant Engineering Division's proposals are now being adopted by the British Standards Institution, as a result of representations through the Mechanical Handling Plant Committee and the British Iron and Steel Federation. Continuous stress-recording instruments are being developed to measure the critical stresses in crane structures over long periods.

Metallurgy

Extension of the Castaing Technique

In the technique originated by Castaing, the composition of small areas (about 1μ diameter) of specimens is determined by analysing the X-rays generated when

Fig. 6.—Ferranti Pegasus electronic digital computer.

the surface is bombarded with an electron beam. The Castaing technique is being developed by Associated Electrical Industries, Ltd., sponsored by the British Non-ferrous Metals Research Association, the British Welding Research Association, the British Cast Iron Research Association, and B.I.S.R.A. The object of the work is to extend the technique to elements of low atomic number—to carbon and nitrogen, if possible. This depends mainly on greatly increasing the intensity of the electron beam. Considerable success has been obtained by arranging for the optical microscope to be independent of the system for forming the electron beam, thus making it possible for the best design to be used for each. For the analysis of elements of low atomic number the apparatus should also be evacuated to prevent absorption of the X-rays by the atmosphere, and the apparatus is being designed so that this can be done.

Structure of Tool Steels

Coarse eutectic structures that are sometimes present in large high-speed steel ingots cause difficulties in forging, and may lead to cracking during heat treatment of semi-finished tools. Attempts are therefore being made to refine the cast structure of high-speed steel by inoculating the liquid metal with numerous crystal nuclei. The object is to produce more finely dispersed crystals and thus reduce the size of the pockets of infilling eutectic. Preliminary experiments have been made in the laboratory but were inconclusive, and works trials are now being carried out in which attention can be given to size of ingot, melting practice, etc. A few positive results have been obtained, but the improvement has not been sufficient to be commercially significant.

One of the important properties of a tool steel is its toughness, but there is a considerable divergence of opinion as to which test gives a satisfactory measure of toughness. Various tests are being compared, including static torsion, torsion impact, and B.I.S.R.A. bend and impact tests. In the last, repeated blows of increasing energy are struck until the specimen fractures. A more reliable estimate of the resilience of the steel should thus be obtained than by conventional impact tests. The B.I.S.R.A. bend and impact tests are also being used to study the effects of different heat treatments on the properties of tool steels.

Operational Research

Computer Installation

B.I.S.R.A.'s electronic computer, a Ferranti Pegasus machine, is now being installed (Fig. 6). It will be used to explore the potential applications of computers in the iron and steel industry, and to help individual companies to assess the results they may expect to obtain from machines of their own.

Much new ground will have to be broken in applying computers to the steel industry, but there is a considerable fund of experience to draw upon. B.I.S.R.A.'s own staff have made use of the computer at Manchester University during the past three years for calculations on ironmaking, steelmaking, and operational problems, and various companies within the industry have small groups working on the subject and have computers on order. There is also the experience of other industries.

In the steel industry, as in many others, the potential applications for computers are in research, in mechanizing clerical work, and in the integration of computers with production units.

In research the B.I.S.R.A. computer will be able to take over many routine tasks, such as statistical analyses of the results of experiments and many other kinds of data. Trained scientists will thus be freed for less repetitive and more creative work. A more exciting prospect is offered by using the computer to tackle problems that have so far remained unsolved because of the sheer length of the calculations entailed. Heat flow and temperature distribution in steel and in furnaces presents many problems of this kind. By bringing within the realm of practical possibility what would once have been regretfully abandoned, a computer can thus extend the scope of research.

The second, and ultimately more important, use of the B.I.S.R.A. computer will be to study the new uses of these machines in the iron and steel industry. Functioning as a central " pilot plant " for the industry as a whole, it will be used to obtain the working knowledge necessary to put computers into service in steelworks.

It is impossible to predict the influence computers may eventually have in management. Nevertheless, it is clear that for some purposes they will eventually replace punched-card equipment and other mechanical accounting machinery, for they are much faster and have greater capacity and versatility, although they require no more operators.

Two important uses of electronic computers in the steel industry are likely to be the scheduling of production (including receiving orders and forecasting deliveries) and stock control. Other applications include calculating wages and analysing, recording, and costing production. In many applications, if a computer is to be exploited to the full, all the information required should be recorded automatically at the point at which it originates.

The Association has prepared a booklet, *Computers and Steel*, describing the use and application of computers in the iron and steel industry; copies may be obtained from the Information Officer of B.I.S.R.A.

The British Welding Research Association

With the transfer of the metallurgical staff of the British Welding Research Association to Abington Hall, near Cambridge, the whole of the Association's research work is now carried on there. In a recent description of the new metallurgical laboratories, reference was made to several items in the metallurgical research programme. The present account of the Association's activities, therefore, is devoted mainly to the engineering researches in progress, mention also being made of activities in the spot welding, non-destructive testing and productivity fields.

THE official opening of the new metallurgical laboratories of the British Welding Research Association was referred to in the September issue of METALLURGIA in an article giving an outline of the Association's current metallurgical research programme. The new laboratories are situated at Abington Hall, near Cambridge. The house and grounds were acquired in 1946, at that time for the purpose of providing accommodation for engineering and resistance welding researches. In 1952 a new fatigue and structural testing laboratory was erected fulfilling the first stage of laboratory development. The opening of the metallurgical laboratories completes the second stage of the scheme and with the transfer of the metallurgical researches from London all sections of the Association's research work are now centred at Abington where a total staff of 100 persons is employed.

Engineering Researches

Structural Design

It is of interest to record that the welded steel frames for the fatigue and metallurgical laboratories were designed in accordance with the plastic theory of design. It is now nearly twenty years since Professor J. F. Baker started investigations into the true load-carrying capacity of rigid frame structures from which the plastic theory has been evolved. When this work was begun it was recognised that any development of a rational design method for rigid frame works would, in practice, be assisted by the use of welding as a comparatively simple, but wholly effective, means of obtaining fully rigid connections. With this important combination it was natural, therefore, that Professor Baker's researches should be supported first by the Welding Research Council and then, since 1946, by the B.W.R.A.

A full appreciation of twenty years work cannot of course be given in this article. Indeed, in order to trace anything like a complete account of the attempts to derive rational structural design methods, a period of very much longer than twenty years would have to be covered. It is probably well known, however, that an authoritative study of the problem of designing structures, in which the wholly arbitrary nature of conventions such as pinned frames and assumed eccentricities of column loads was squarely faced, resulted in the pre-war publication by the Steel Structure Research Committee of what was claimed to be the first rational method. The S.S.R.C. method was not simple in application and, probably more important, it dealt only with the elastic behaviour of structures, and gave no credit for the additional strength possessed by rigid frames after the onset of yielding. In developing the present theory the behaviour of elements and complete structures in both the elastic and plastic ranges has been studied, and the principal basis of the design method rests upon the calculation of actual load-carrying capacity, that is, the ultimate load capacity at collapse. Thus the structure is, in effect, designed to fail under a factored load. This approach may be contrasted with the conventional one of designing to some maximum stress which may be justifiable in the case of the conventional pin-jointed frame, but is inadequate for the rigid frame.

One of the features of the plastic design method is its proved economy in material; early forecasts of savings in steel from 10 to 25% have in recent years been amply realised in many actual structures. Because of this feature, and because the method is notably straightforward in application, there is today a worldwide interest in it. Many overseas visitors were among the 110 members of a recent symposium on the Plastic Theory of Structures organised by Professor Baker and his staff at Cambridge University, where the research is still proceeding. An important part of the research is the testing of full-scale structures. Nine such experiments have been undertaken at the testing site in the grounds of the B.W.R.A. Research Station.

Brittle Fracture

Failures of welded structures such as ships, bridges and oil tanks, due to brittle fracture, have, as is well known, prompted intense research activity in many countries over the past 10–15 years. The present work of the Association in this field is of more recent origin. It was started by Dr. A. A. Wells as a fundamental investigation of the mechanics of notch brittle fracture, an investigation which led to the consideration of the value of laboratory tests on comparatively wide plate specimens as a means of studying some of the basic aspects of actual structural behaviour. Fracture tests on 36 in. wide plates up to 1 in. thickness were proposed, clearly creating the need for a special test rig. The rig ultimately designed and constructed is shown in Fig. 1. Essentially, it comprises of four hydraulic capsules which together produce a maximum tensile load of 700 tons. The load is applied to heavy end members to which the specimen plate is attached by transverse butt welds. After the completion of a test the specimen is cut away at these transverse joints and the end members are then available to be used again. During the course of a test, loads and extensions are automatically recorded and temperatures are measured at critical points. Most tests are carried out with the specimen plate at a temperature below ambient, the necessary cooling being obtained by packing solid carbon dioxide into flat boxes which contain the dry ice against the surfaces of the

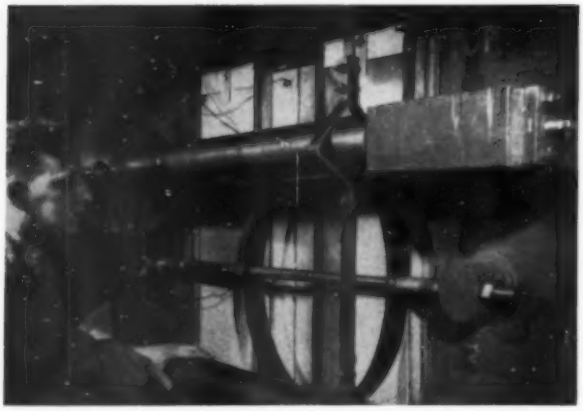


Fig. 1.—Special rig for brittle fracture tests of 36-in. wide steel plates.

plate. In Fig. 1, these boxes are seen in position, covering all but a narrow vertical portion of the specimen.

The principal line of investigation in the wide plate experiments has been directed towards establishing the conditions which govern the onset of brittle fracture in welded mild steel structures. For this investigation, 1 in. thick plates, 36 in. wide, with a central, longitudinal butt weld have been used. The fractures are initiated from artificial notches in the form of fine saw-cuts made in the edge preparation of the plates before depositing the longitudinal weld. As in other kinds of transition temperature test the selected temperature level is first established and loading to fracture then proceeds, and as in the other kinds of test a transition behaviour has been defined, in this case for welded specimens containing the residual stress field associated with the longitudinal butt joint. At temperatures above a critical range the yield stress load is sustained before the initiation of fracture ; under the high externally applied load the fracture is then usually propagated for the full width of the plate. Below the critical temperature range brittle fractures of a few inches in length only are obtained at quite low applied loads, and to re-initiate and propagate these cracks yield stress on the nett area is again required. These extremes of behaviour bound the critical temperature range within which it is possible to obtain full width fractures at stress levels well below yield, and hence bearing direct relationship with known casualty conditions.

This pattern of behaviour for " as-welded " plates has now been reproduced for several qualities of mild steel, including ND I and ND IV grades. The critical temperature range is dependent on steel quality and it has been observed that this range agrees well with the Robertson arrest temperature. The particular value of the test in the structural sense is, however, well emphasised by its important demonstration of the influence of residual welding stresses. It was stated that the transition behaviour had been found for " as-welded " specimens. For these, the contribution of the residual stress field was believed to be a basic factor, exemplified, for instance, by the generation of short cracks at subcritical temperatures. Although the region of the short crack cannot be separated entirely from metallurgical changes consequent upon welding, its close correspondence to the availability of internal energy suggested a marked dependence on residual stress for initiation and limited propagation. To test this energy theory, experiments on stress-relieved plates have been carried out in collaboration with the Research Department of Colvilles Ltd., where a duplicate test rig is being operated. The experiments have covered several stress-relieving methods, and while some have proved more effective than others it is probably only relevant here to mention that the two most effective—650° C. furnace treatment and mechanical straining—have shown convincingly that the removal of residual stresses has a profound effect. When such stresses are removed the transition behaviour no longer applies, and full yield stress is required for initiation over the whole temperature range. Another aspect associated directly with welding, namely the influence of the type of electrode used for making the longitudinal butt weld, has also been taken into account. Experiments have shown that for otherwise similar conditions, the temperatures at which full width fractures are produced are higher with rutile electrodes than with low-hydrogen electrodes. This result appears to be linked with the greater tendency of the rutile weld metal to spread initial flaws.

Fatigue

A number of investigations of the fatigue properties of welded joints are in progress. They include a comprehensive programme of tests on fusion welded butt joints in mild steel plate, in which S/N curves are being determined with particular reference to the strength value corresponding to 2×10^6 cycles. The programme embraces many variables, for example, plate thickness, welding method, plate edge preparation method, and the influence of weld reinforcement shape and of stress-relieving. The plate material is principally of B.S. 15 quality and two thicknesses, $\frac{1}{2}$ in. and $1\frac{1}{4}$ in., are being used. These thickness limits permit the comparison of several types of weld which are at present being tested in the form of a transverse butt joint under axial loading. Two loading cycles, pulsating tension and alternating, are to be applied, the tests being undertaken in a 100 tons capacity hydraulic fatigue machine. The broad scope of this programme permits the study of the influence of several aspects of weld quality. Particular attention will be given, however, to the influence of internal defects, a matter which has already been investigated in some detail for a different type of joint—the circumferential pipe butt weld. The data already available on this problem show that for the " as-welded " forms of joint (in this context a joint to which surface dressing is not applied) fatigue behaviour is strongly influenced by surface stress-raisers ; the effect may indeed be sufficient to override many kinds of internal defect.

Axial load fatigue tests are also being carried out on aluminium alloy plate specimens with transverse butt welds. The tests, which are being undertaken for the Association by the Metallurgy Department, Cambridge University, are in a preliminary stage and involve two alloys, NP5/6 and HE30, the former in rolled and the latter in extruded plate form, $\frac{1}{4}$ in. in thickness. The high temperature fatigue properties of welded joints in heat resisting sheet materials is another investigation recently started. Here again loading is applied axially, but an alternating stress cycle (mean load zero) is used to minimise creep effects. Several materials will be tested, the first being the Nimonic 75 alloy, with welded

joints made by the manual and automatic argon arc processes.

Experiments to determine the strength of fabricated thin gauge box-sections under various forms of fatigue loading are being carried out. These are primarily of interest in relation to motor car construction in which the thin gauge box-section member is commonly a principal element of chassis frames. The representative test specimens are fabricated by three welding methods—metal arc, automatic carbon arc and spot welding—all of which are applied in practice in this type of construction. A comparison of the merits of the different types of section is being made on the basis of alternating torsion and alternating plane bending tests, the latter including tests about each of the two principal axes of the cross-section. For all tests, resonance vibration techniques are employed ; the test rig for the torsion tests is shown in Fig. 2.

Pressure Vessels, Storage Tanks and Pipe Lines

The development of experimental methods of stress analysis has in recent years given undoubted impetus to the investigation of many design problems. This is particularly true in the field of pressure vessel and pipe line engineering, in which detail design has essentially been based on what might be called the rules of experience, allied to good welding practice. Such rules certainly apply in the case of the calculation of the reinforcement required at branch openings in pressure vessels, one of the design problems under investigation by the Association. With the active assistance of member firms it has been possible to work on full scale experimental vessels for the measurement of stress distribution at such openings, and quite extensive data have now been collected. In parallel with the actual measurement of stresses a theoretical treatment of the problem of calculating maximum stress intensification factors at openings has been considered, and the investigation has now reached a stage where a check against calculated results is being made. This check involves the testing of a full scale vessel with branch openings of a size that would normally be reinforced with heavy compensating plates. The theoretical treatment indicates, however, that for the thickness and diameter of vessel concerned, these branch openings require no reinforcement and the tests will be carried out to confirm this prediction.

Experimental work is also proceeding in connection

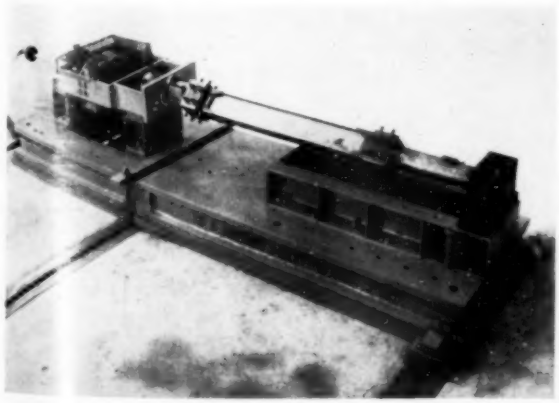


Fig. 2.—Alternating torsion test rig.

Fig. 3.—Test on oil storage tank plate with full size manhole opening.

with another problem of reinforcement design, in this case for manhole openings in oil storage tanks, for which the standard reinforcement is a plate attached by welding to the outside surface of the tank. Here, the stress field to be considered is essentially uni-axial. This makes it possible to study design variants with specimens of less than full-scale, in view of the fact that tension loading on flat plates substantially reproduces the condition of service use. In the laboratory, $\frac{1}{4}$ scale models of manhole openings are tested in this way. The results can be interpreted with confidence since a check was made against the full-scale construction in the early stages of the work. For the full-scale experiment an unusual test arrangement was devised ; it is shown in Fig. 3. The approximately square test plate is curved to a typical tank radius and contains a manhole opening of full size with the conventional type of reinforcement. At the left and right hand ends the test plate is welded to a rigid strong back ; along the other two sides the arched gap is sealed by channel sections bearing against rubber packing and tightened by transverse tie bars. With water pressure between the plate and strong back the plate has sufficient freedom to deflect upwards, developing uni-axial tension against the reaction of the rigid ends. In this manner test loads producing full yield of the plate were obtained.

A detailed investigation of the design of branch connections for welded pipe lines has recently been completed. This again involved experimental stress analysis, stress distributions being measured for five different forms of loading ; these were : internal pressure, axial load on the branch, bending of branch in two planes, and twisting of the branch. The first two proved to be the most severe in terms of the measured stress concentrations. Of the many reinforcement designs tried, the most effective was that known as the " tri-form " construction ; the conventional collar reinforcement was found to be reasonably effective. Current work in the pipeline field is concerned with the strength of gussetted bends. These are bends, normally of large diameter, fabricated from segments of straight pipe.

Resistance Welding Researches

Although there is a background of quite extensive experimental work on spot welding, aimed primarily at

establishing optimum welding conditions, the effectiveness of techniques for measuring weld strength and ductility has never been fully assessed. With the extension to a wider range of steels in the application of this process, an assessment of testing methods has become an important requirement and is now being undertaken. The hypothetical behaviour of spot welds in ideal elastic/plastic material has been chosen as a basis for comparing the results of actual tests such as shear, tension and torsion. For torsion and shear the relationship between theoretical and actual strengths could be represented diagrammatically by straight lines passing through the origin. Two sets of results were obtained for the tension test, a higher strength group showing mainly slug type fractures and lower strength group associated largely with face type fractures. The ability of the tension test to discriminate ductility properties was thus shown, and arising out of this it has been suggested that the ratio of experimental to theoretical tension strength will give a more significant measure of spot weld ductility. As part of this investigation a machine for testing single spot welds in torsion was designed and constructed by the Association. The machine records the result of a test in the form of a torque/angle of twist diagram.

Reference has already been made to the increasing application of spot welding. Applied to hardenable steels the use of a welding cycle with post heating may be necessary. A proper development of the process for this class of work, therefore, depends much on the provision of some rational basis for determining optimum welding conditions. A fundamental study of this problem in which both the measurement and the calculation of spot weld thermal cycles is being tackled, is in hand. As a next step it will be necessary to define the metallurgical changes in hardenable steels which arise as a consequence of the applied thermal cycles.

Other resistance welding investigations in progress include work on the spot welding of heat-resisting alloys, recently started, and a review and modification of previous recommendations for the projection welding of mild steel.

Non-Destructive Testing

The Association has recently revised its well known memorandum on non-destructive methods for the examination of welds. The general subject is, however, being kept under active consideration, and extra-mural researches on the radiographic and ultrasonic methods are proceeding. A study of the effect of dressing weld surfaces has shown that this practice gives improved radiographic sensitivity to fine defects. In a separate investigation, a comparison has been made between radiographs obtained from X-ray and gamma-ray sources. The radiographs were taken from welds in mild steel plates in thickness of $\frac{1}{2}$, 1, $1\frac{1}{2}$ and 2 in. For thicknesses less than 2 in., the X-ray source was found to be superior, but the difference in results between X- and gamma-ray sources became less marked as thickness increased up to 2 in. Iridium 192 was judged to be satisfactory for thicknesses 1 in. and upwards, as was Caesium 137, and reasonable at $\frac{1}{2}$ in. thickness, but Cobalt 60 was found unsatisfactory for thicknesses of less than 2 in.

In ultrasonic testing the importance of the surface condition of the inspected part has often been asserted rather than quantitatively demonstrated. Results obtained under carefully controlled conditions are showing that the influence of the surface is not necessarily related simply to the surface roughness apparent to the eye. Whilst very irregular surfaces can impair ultrasonic testing by limiting the contact with the probe, reasonably good contact is in itself no criterion of satisfactory testing conditions. In fact, in some cases an apparently rough surface has given better results than a smooth, bright surface. This investigation is being continued.

Productivity Measurement

Productivity in welding is the subject of an investigation being carried out with the co-operation of member firms. A method of making comparisons of productivity, if necessary involving different products, has been evolved. In addition, a new method of measuring and forecasting arc welding costs has been worked out and has been shown to have important advantages over existing methods.

Oxygen Packed Lance Solves Diecasting Furnace Problem

THE use of an oxygen packed lance at the Wordsley (Worcs.) factory of Fry's Diecastings, Ltd., is making possible the recovery of metal from crucibles which are subject on occasions to premature breakdown. The crucibles, made from highly refractory material, are used for the melting of aluminium bronze and brass. Occasionally, they break down prematurely and the metal falls into the furnace bottom. After cooling, a disc of metal of up to 36 in. dia. and 3–7 in. thickness is formed. In view of the fact that normal furnaces are not sufficiently large to melt discs of metal of this size, it is necessary to cut them into small pieces. Two cutting methods, an abrasive cutting-off wheel and a band saw, were tried without success. After consultation with British Oxygen Gases, Ltd., however, it has been found possible to cut the metal with the aid of an oxygen lance. The lance, a standard 21 ft. length of $\frac{1}{4}$ in. gas steel tubing, is packed with $\frac{1}{8}$ in. dia. pure aluminium rods and $\frac{1}{8}$ in. mild steel rods, and oxygen is then passed through at 90–100 lb./sq. in.

The discs of metal are removed from the furnace when solidified but still hot, and a standard oxy-acetylene cutting blowpipe is used to start the reaction of the lance. The addition of the rods provides the oxidisable material lacking in the metal which is being cut, and enables sufficient heat to be generated to melt the non-ferrous disc along the line of cut.

Before the firm solved the problem of cutting the discs, the metal had to be sold for scrap at a low price. The cost of the equipment supplied by British Oxygen was entirely recovered on the first operation. Although the crucibles break down only occasionally, it is essential that the metal is recovered immediately. The firm are able to effect recovery themselves as the equipment can be easily operated after an initial demonstration. The oxygen packed lance can be used for cutting oxidisable or non-oxidisable material.

Change of Address

THE Selson Machine Tool Co., Ltd., have moved to more extensive offices and showrooms at 41-45, Minerva Road, North Acton, London, N.W.10.

The British Non-Ferrous Metals Research Association

By E. C. Mantle, M.Sc., F.I.M.
Chief Liaison Officer of the Association

Although a great deal of the Association's research programme is concerned with metal manufacturing processes, there are many projects relating to the properties and applications of non-ferrous metals, fabrication techniques, etc., as befits an Association whose membership includes a large proportion of users of non-ferrous metals. Included in an account of some of the main items of interest in the Association's activities is a reference to a projected study of thorium which has possibilities as a fuel in nuclear power stations.

IT may seem a far cry from the safety of electricity supplies to research on the embrittlement of copper by hydrogen, yet the connection is, in fact, very close. The windings of all the large modern generators have to be cooled by hydrogen, otherwise they would overheat. As it is, they run at about 150° C., a temperature assumed to be safe for the copper windings. High conductivity copper is known to be embrittled by contact with hydrogen at high temperatures and, as an insurance against possible troubles, a research was undertaken as a matter of high priority to determine the risk—since shown to be negligible—of running high conductivity copper in hydrogen at moderate temperatures for very long periods.

This is an example of the type of research, unspectacular but often vitally important, that the B.N.F. is frequently called upon to undertake. A familiar material being used in a new application calling for a fresh evaluation of its properties ; a need for modifications to a class of alloys to overcome some inherent drawback ; research to facilitate closer control over methods of manufacture or to enable plant to be utilised to better advantage—researches of all these types can be found in the current programme, which contains about forty active major research projects.

It may come as a surprise to many people to learn that the Association's membership contains a large proportion of users of non-ferrous metals. Although, naturally, a great deal of the research programme is concerned with metal manufacturing processes, there are also many projects relating to the properties and applications of non-ferrous metals, fabrication techniques, etc. These include corrosion studies, determination of the mechanical properties of alloys, with particular reference to high temperature performance and fatigue properties, inspection tests for electroplated and anodised coatings, and high-temperature brazing.

As a result of researches such as these, a great body of information and experience of the uses of non-ferrous metals has been accumulated over the years. This is all available to be drawn upon by the members of the Association, and users of non-ferrous metals have in this a unique consulting service capable of giving sound practical advice on metallurgical matters. This important section of the Association's membership is growing continually and already contributes some 20% of the Association's total income from industry. The users of non-ferrous metals come from all sections of industry : transport, electrical engineering, aircraft, oil, chemicals and marine engineering. Of more than 1,200 enquiries dealt with in 1956 by the consulting service run by the Association's Liaison Department, over a quarter originated from member firms in these categories. These members also borrow extensively from the Association's Library.

More recently, the existing " user " members within the Association have been joined by the main groups concerned with the development of nuclear power in this country, and considerable financial support has been obtained for work in the nuclear power field.

Nuclear Power

Much thought was given to the way in which the Association could best make use of its resources to assist with the development of nuclear power. The aim has been to make use of the experience already within the organisation and extend it to problems concerned with nuclear power, rather than to initiate fields of research entirely new to the Association in which other laboratories might be more experienced or better equipped. The design of the first generation of nuclear power stations was considered to be too advanced to allow time for more than the minimum research to fulfil the requirements of the design engineers, and work of this kind is best left in the hands of the individual firms. It was decided that the Association could more profitably direct its energies towards a metallurgical exploration of reactor materials which might be of interest in future stages of nuclear power development. For this reason most of the research effort is to be devoted to a broadly based examination of the properties of thorium and its alloys. In addition, the information services of the Association have been augmented to ensure adequate coverage of this new branch of metallurgy, and it is intended that eventually the Association will play a large part in the exchange of information on these matters.

Thorium is an attractive fertile material for conversion into fuel, and there are many factors in favour of it as opposed to uranium. It is more abundant. The thorium 232/uranium 233 cycle is theoretically capable of using up 100% of the available thorium, whereas the natural uranium reactor can use only a small proportion of the available uranium. The thorium can all be used in a thermal reactor, the design and performance of which is familiar. On the other hand, plutonium, the end product of the uranium 238 cycle of the present design of reactors can only be burnt in a fast reactor, control of which presents more serious problems.

Spread of drop test used for experiments on high temperature brazing. The brazing material is placed on a strip of heat-resistant alloy which is quickly brought to the brazing temperature by passage of an electric current. The amount the drop of brazing material spreads is determined under various conditions.

However, there are considerable metallurgical difficulties to be overcome in using thorium. Nuclear power reactors must work at relatively high temperatures to attain sufficient thermal efficiency for economic power generation, and the strength of the fuel elements at the operating temperature is an important consideration. Creep of these fuel elements after long exposure to high temperatures is one of the biggest metallurgical problems that has to be overcome and it is this aspect that will feature largely in the first stages of the Association's work on thorium.

From the point of view of developing strong alloys, thorium is a most difficult subject, since few elements have more than a very restricted solubility in it. Cerium is completely miscible, but is difficult to produce in a pure state, and the rare earth metals which usually contaminate cerium have high neutron capture cross sections, making them unsuitable for incorporation in reactors. Carbon has a limited solubility at high temperatures, but at lower temperatures the solubility is much more restricted and there is a possibility that massive grain boundary precipitates might cause brittleness. Zirconium and uranium itself are other possible alloying additions, though each has a very restricted solubility at low temperatures.

The techniques which are being used in the preparation and melting of these thorium-base alloys are similar to those used for preparing titanium and zirconium alloys, with which the Association has already had considerable experience. Research on titanium alloys has been in progress on a modest scale in the B.N.F. for several years now, and work on the development of creep-resistant zirconium alloys has also been going on for some time.

Although research on these newer metals steals the limelight, the major part of the programme is concerned with the more traditional non-ferrous metals and some of the topical items in this programme are mentioned below.

Instrumentation

Closer control over quality and the need, for economic reasons, to reduce process scrap to a minimum has led to keen interest in instrumentation. This is a large subject and obviously any one laboratory can only concentrate on a few aspects. Nevertheless, the Research Association can provide a most useful service to its members by keeping itself informed of developments in instrumentation and new applications of instruments to production control and inspection. Actual experimental work has been restricted to a few specific objectives. One example is the development of the B.N.F. Coatings Gauge which is now in commercial production.

There has long been a demand in the electroplating industry for an inspection tool to enable the thickness of the deposit to be measured without destruction of the plating. The B.N.F. Coatings Gauge does just this. The instrument works on a thermo-electric principle, and by the simple application of a heated probe to the surface of a plated article it is possible to determine, with calibration curves, the thickness of the deposit in a matter of a few seconds. With nickel deposits on steel or brass, the thickness was determined to an accuracy of 0·1 mil. in demonstrations of the commercial instrument. The instrument enables 100% inspection checks to be made on important electroplated articles and should do much to assist in maintaining high standards of quality. It is also invaluable for making rapid surveys over the surface of articles to determine the variation in thickness of coating from point to point, and is thus likely to be most useful for establishing the best method of jigging any particular article in the electroplating vat to ensure good coverage. Although it is envisaged that the main use of this instrument will be for measuring the thickness of nickel coatings, provided it is suitably calibrated it can be used for measuring the thickness of any other type of electrodeposit, and by using two probes it is even possible to determine separately the thicknesses of some duplex coatings, such as nickel on an undercoat of copper.

At present practical work is going on in the laboratory to obtain more basic information about eddy current methods of testing, to provide the staff with the necessary data to assist members in the application of this method of inspection to different kinds of non-ferrous metal articles.

Development work is also being carried out on the automatic control of bright annealing furnaces employing burnt town's gas as a protective atmosphere. In some of these furnaces the mixture of air and gas burnt to heat the furnace is controlled in such a way as to provide the protective atmosphere. As a result of changes in the loading of the furnace, which affect the gas supply needed to maintain the furnace at temperature, wide fluctuations in the protective atmosphere can arise. Experiments on a furnace in a member's works have shown that with suitable instrumentation and control equipment these fluctuations can to a large extent be avoided and a close control maintained over the composition of the atmosphere in the furnace. In this case the instruments and control equipment used were already commercially available, and the Association's rôle had been to interest the equipment suppliers in this problem and organise the trials.

X-Ray Fluorescence Analysis

Some thirty years ago the Association pioneered the application of the spectrograph to metallurgical analysis. Interest in this subject has been maintained over the years and spectrographic analysis in the Association's

laboratories has now reached a high peak of efficiency. Modifications are at present being made to the Production Control Quantometer, which was installed in the laboratories in 1951, to enable the instrument to deal with about 90% of the normal spectrographic analytical work. However, there are limitations to spectrographic analysis, particularly when dealing with large amounts of major alloying constituents, where even direct reading equipment is insufficiently accurate. X-ray fluorescence analysis seems to fill this need and the Association has this year begun a critical evaluation of its applications to the analysis of non-ferrous metals.

In this method of analysis the specimen is mounted in close proximity to an X-ray tube which excites the X-ray spectrum of the specimen by fluorescence, just as a spark or arc excites the optical spectra in ordinary emission spectrography. The X-ray spectrum contains a series of wave lengths characteristic of the elements present in the specimen, and is analysed by simultaneous rotation of a crystal and a geiger counter whose output is taken to a suitable recorder. This method of analysis is non-destructive, the form of the sample is relatively unimportant and, since the area on the sample examined is large, errors due to segregation are reduced. The spectra are much simpler than optical spectra excited by arcing or sparking the metal, so that identification of elements is easier, and the indications are that this method of analysis will be suitable for dealing with major alloying constituents with sufficient accuracy for routine control.

In its present form this method of analysis is incapable of determining the lighter elements having atomic numbers less than 11, and the Association's equipment is unlikely to be able to deal with elements having atomic numbers less than 20, though this covers most of the common metals. The method is more suitable for the analysis of constituents having concentrations greater than 1%, although for qualitative analysis lower concentrations can readily be detected. The spectrograph appears to be more suitable for the determination of trace elements.

Analysis with Ion Exchange Resins

In ordinary chemical analysis the Association's work is concerned with the application of new techniques which will simplify, speed up, or increase the accuracy of determinations. One of the simplest ways in which this can be achieved is by the application of ion exchange methods, and in the past year or two several methods involving ion exchange techniques have been worked out. For some purposes it is sufficient to use a column of cellulose pulp as the ion exchange material; for others a column of special ion exchange resin is necessary. In the main these ion exchange techniques are used as an alternative to precipitation and filtration or electrodeposition for removing interfering elements in the course of analytical determinations. For example, when a colorimetric method is used for estimating small amounts of phosphorus in copper alloys, the blue colour of the copper ion interferes. By passing the solution of the alloy through an ion exchange column in which the copper is retained, this blue colour may be removed and the colorimetric finish for phosphorus carried out without difficulty. The green colour of nickel plating solutions interferes with the determination of constituents such as chlorides and borates. Passing the solution through a cation exchange column is a simple way of removing the nickel ion so that the determinations may be carried out in colourless solutions.

Research on alloys of metals such as titanium and zirconium necessitates frequent determinations of the oxygen contents of the alloys since the presence of oxygen can have a pronounced effect on the properties. In the apparatus shown, the oxygen is converted to carbon dioxide, the pressure of which is subsequently determined, and from this figure the oxygen content of the material obtained.

Another application to electroplating is determining the amount of trivalent chromium present in chromium-plating solutions. In this case the trivalent chromium is absorbed on a cation exchange column and, after washing the column free of hexavalent chromium, the trivalent chromium is elutriated from the column and determined by titration with ferrous ammonium sulphate of appropriate strength.

An interesting point in connection with ion exchange materials is that all the water used for analytical work is now purified by ion exchange methods, and has a lower conductivity than the distilled water previously obtained from conventional laboratory stills.

Foundry Work

The paper by Ruddle and Cibula presented at the Institute of Metals Symposium in the Spring of this year, provides an admirable review of the work the Association has carried out into the casting of non-ferrous metals over the past few years. The biggest gap in our knowledge of foundry processes is now that concerned with running and gating castings, and this subject forms the main part of the Association's research programme for the foundry industry at the present time.

Essentially the problem is one of introducing the metal into the mould in a non-turbulent manner in order to avoid dross entrapment and injection of air bubbles, though gating to induce the correct thermal gradients to facilitate feeding is also of importance in some types of castings. Many novel gating systems have been described in the literature, particularly in America, and a number of these have been examined in the Association's work. Some of these have proved themselves capable of simplification without detriment to the main objectives of the systems, and the stage has now been reached where, after tests in the laboratory with representative

Columns of ion exchange materials are in regular use in the analytical laboratory and frequently allow lengthy chemical separations to be short-circuited. The simplicity of the apparatus required can be judged from this photograph of a laboratory assistant carrying out an ion exchange separation.

types of castings, these simplified " ideal " gating systems are ready to be tried on production castings.

The Association has been called upon by the foundry industry to settle a number of outstanding technical difficulties over the formulation of British Standards. In one case doubts were expressed about the maximum temperature permissible for certain gunmetal steam valves. Failure is most likely to occur through distortion of the casting under prolonged stressing at the operating temperature, and the common gunmetals were compared from this point of view by carrying out creep tests at the temperature in question. A similar point arose about the application of hot-stamped brass valves at elevated temperatures, and here again the issue was decided by a series of creep tests.

The possibility of sulphur in gunmetals causing difficulties in casting or harming the mechanical properties was raised by another British Standards Committee. Although many foreign specifications limit the sulphur content of gunmetals and phosphor bronzes to a low level, up till now no limits have been placed upon sulphur in equivalent British Standards. With the increasing use of high sulphur fuel oils for melting, sulphur contents have risen considerably in recent years, and the presence of sulphur has been blamed for a variety of foundry difficulties. All references in the literature suggest that sulphur has no harmful influence, and there were no apparent reasons for the restrictions in various specifications. To clear up the matter, the effect in these alloys of sulphur contents up to 0·3% has been investigated.

High Strength Light Alloys

The high strength aluminium alloys extensively used in aircraft and for other highly stressed engineering applications have not the same resistance to corrosion as the less alloyed materials, and for many purposes these high strength alloys need some form of protection. In sheet form, cladding with pure aluminium has been used for many years, but this method cannot be applied to complicated extrusions or forgings. Sprayed coatings of aluminium or a suitable aluminium alloy are an alternative, and the protection afforded by these coatings has been evaluated over the past two or three years in some tests carried out in the Association's laboratories and at its marine corrosion site on the South Coast. Adequate protection under most circumstances can be obtained by spraying these high strength alloys with more corrosion resistant aluminium coatings, even where mechanical damage causing small gaps in the coatings occurs.

While protection by metal spraying is a satisfactory cure, the development of means of making these alloys inherently immune from corrosion problems would provide a better solution, and a large part of the Association's work for the light alloy industry is directed to examining the reasons for the susceptibility of these alloys to corrosion, particularly their stress corrosion tendencies, with a view to developing methods of treatment to reduce this susceptibility, or to produce new alloys with comparable mechanical properties but less liability to stress corrosion.

There is an increasing interest in the applications of aluminium alloys to land transport. The medium strength light alloys are most suited to these applications, but the use of the alloys is to some extent hampered by lack of data, particularly referring to fatigue. A programme of fatigue testing in hand includes not only the determination of ordinary endurance limits, but also the examination of the effects of notches, such as might be introduced by rivet and bolt holes, and the effects of fretting which occurs in assemblies of this kind. For much of this work the accelerated method of assessing fatigue, described in METALLURGIA for September, 1956, suitably modified, is to be employed.

For some parts of the work, fatigue under direct stressing will have to be determined, and two Vibraphore direct stressing machines are being installed to augment the range of rotating cantilever machines already available.

Improvements in Copper Alloy Production

Several researches have a direct bearing on wrought copper alloy production. One has the aim of extending the uses of the Ajax-Wyatt low frequency electric furnace. This has been employed for many years for melting brass in the wrought copper alloy industry, and it is only comparatively recently that attention has been turned to using this very economic melting unit for other copper alloys. A few years ago experiments were made with its application for melting ordinary phosphorus-deoxidised copper, but at first the linings failed so rapidly as to make the method uneconomic. Several member firms were at this time carrying out experiments with these furnaces, and collaboration among them was arranged to enable trials of different refractories, various ramming techniques, and improved methods of pre-firing the furnace lining to be facilitated. Marked success was obtained and this type of furnace is now regularly used for melting phosphorus-deoxidised copper and similar alloys. There is, however, still the problem of finding a satisfactory refractory to allow the furnace to be used for higher melting point materials, such as 70/30 cupro-nickel. As small scale laboratory experi-

(Continued on page 185)

The British Cast-Iron Research Association

By G. R. Woodward

Manager, Intelligence Department of the Association

With the increasing scope of the Association's activities, additions have been made from time to time to the buildings at the Bordesley Hall headquarters. This year a new melting shop has been officially opened and a brief description of the facilities provided precedes an account of the progress made in a wide range of investigations and a reference to the work of the development and operational research groups.

ONE of the chief events of the year has been the inauguration of the new experimental melting shop by the President (MR. J. J. SHEEHAN) on July 3rd, 1957, the first of two Open Days held by the Association, during which well over 500 visitors inspected the laboratories and the work in progress at the Alvechurch headquarters.

The new shop, which covers an area of 5,000 sq. ft., is furnished with sand preparation and moulding equipment and a 5-ton S.W.L. electric travelling crane. Its melting resources include a number of oil-fired crucible furnaces and electric melting units. Facilities for cupola melting, including hot-blast, will be installed later; the cupola furnace will be provided with a melting zone which can be readily removed and replaced by another section so that melting can be made under acid, neutral and basic conditions, with and without water cooling.

Internal view of new melting shop.

Crucible melting includes two 250-lb. capacity tilting furnaces and one lift-out furnace of 80-lb. capacity. The melting rates and maximum temperatures obtainable with the two larger crucible furnaces have been increased by incorporating larger burners and by increasing the air and oil input; two fans in series supply the air at a pressure of about 40 in. S.W.G. The electric melting equipment consists of four high frequency furnaces of 10, 5, 2 and 1-cwt. capacity, and the installation includes some special features incorporated by the manufacturers in consultation with the Association.

The annex to the melting shop is equipped for rough grinding and shotblasting, heat treatment and core-making, and for carrying out small experimental melts. Also housed in this supplementary shop is a vacuum melting furnace acquired from the U.S.A.; it consists of a 30 kW. high-frequency generator which will melt up to 30 lb. of metal in vacuum or controlled atmosphere.

An investigation recently begun concerns the collection of data to support the case for raising the present limitation of 450° F. on cast iron for steam engineering applications, and this has necessitated the installation of new equipment. Low temperature growth tests up to 600° C are in progress, and a battery of six creep machines has been acquired to enable creep tests to be carried out on materials evaluated on the basis of these growth tests.

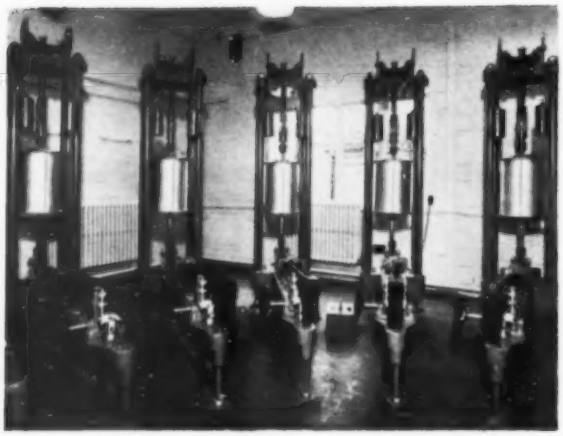
Research Programme

Soundness of Iron Castings

The scope of this investigation has been extended during the year. Factors governing the type of surface depression or sinking defect which occurs from time to time under bosses in light section castings are under examination, and pouring temperature, composition, and mould hardness are among the variables being studied. The effect of design variables (including running methods) on sinking under bosses on thin plates is being investigated.

The sporadic occurrence of shrinkage defects in iron castings for no apparent reason presents a peculiarly difficult problem. Some experimental work on K-bars cast in green sand under conditions approximating to those obtaining in a commercial foundry has shown that the average volume of surface shrinkage defects was generally reduced by:

(*a*) lowering the maximum furnace temperature;
(*b*) reducing the melting time; raising the pouring temperature;
(*c*) raising the carbon content;



Some of the creep-testing machines recently installed.

(*d*) lowering the silicon content ;
(*e*) raising the manganese content ;
(*f*) raising the sulphur content ;
(*g*) raising the phosphorus content ;
(*h*) lowering the shatter index of the sand.

These observations must, however, be cautiously applied in practice, since alterations in these variables can cause troubles other than shrinkage defects. Internal porosity was found to be most pronounced in bars where there was a high phosphorus content in conjunction with a low carbon content, particularly when the metal was inoculated in the ladle with ferro-silicon. Superheating the metal in the furnace reduced porosity. It was found that bars cast in CO_2 process moulds gave less shrinkage and porosity than those made in green sand. One of the most interesting findings in this particular investigation was that wide variations in the oxygen content of the metal did not appear to influence shrinkage and porosity in the K-bars studied.

Other work in hand referring to problems of soundness includes :

(1) Operational research studies in members' foundries to elucidate the principal factors responsible for drawing in light castings.
(2) A study with reference to ingot moulds involving an examination of mould properties in relation to casting dimensions.
(3) An investigation of the soundness of nodular cast iron keel block test-pieces.
(4) A study of the solidification mechanism of irons of various compositions, using microscopic and thermal analysis to determine the relation of the solidification sequence to the shrinkage characteristics of the material.

Mechanical Properties

The work on evaluating cast irons for steam engineering applications has already been mentioned. Tests in steam at Hams Hall "A" Power Station are being carried out at a temperature of about 430° F., and it is hoped shortly to supplement these with tests at 650°, 750° and 850° F. in other power stations.

Work recently completed on the properties of the pearlitic nodular cast irons has shown that these materials have high transition temperatures, which in the notched impact test are above 100° C. In an unnotched impact test pearlitic nodular irons may still have transition temperatures above room temperature. It has been suggested that the inferior tensile properties and elongations which are sometimes obtained in materials with good pearlitic nodular structures occur in such materials because the ductile to brittle transition range for tensile loading is above room temperature, and tests made on a series of irons in which the silicon was increased to raise the transition temperature tend to confirm this theory. In fact, it has been shown that the tensile strength and elongation of a pearlitic nodular iron decrease as the transition temperature is raised and, tested above the transition range at 100° C., all the pearlitic nodular irons examined had good tensile properties which did not vary significantly with silicon content. This theory may also partly account for the superior properties of normalized pearlitic nodular irons at room temperature, particularly in materials which do not develop optimum as-cast tensile properties at room temperature because they are in the transition range. The decrease in the transition temperature of normalized materials may also account for the somewhat higher elongations of the normalized irons. Subsequent work on this subject has been concerned with the effect of trace elements in the raw materials, and will shortly be published in this country.

The tensile properties of two pearlitic commercially produced nodular irons were examined for temperatures up to 600° C. These irons were found to have similar properties at room temperature, but markedly different properties in the range 450°–600° C., and this difference was subsequently found to be due to a difference in phosphorus content, the iron which gave the higher tensile strength and good elongation at 500° C. containing 0·068% phosphorus, whilst the iron with the inferior tensile strength and poor elongation had a phosphorus content of 0·036%. During this investigation it was found that arsenic, which occurs in the same group of the Periodic Table as phosphorus, also improves the short time tensile properties of pearlitic nodular irons at elevated temperatures, and it is suggested that a phosphorus content of 0·1%, or an addition of 0·1% arsenic would be advantageous where good high temperature properties are required in these materials.

An attempt is being made to evolve a rationalization of the mechanical properties of grey cast irons in relation to composition and structure, taking fully into account the theories advanced by various Continental workers for high phosphorus materials. Work has already been published in which, by using the concept of degree of eutectic saturation, or carbon equivalent value, the relationship between chemical composition and strength and hardness, and the dependence of the properties on the rate of cooling, have been illustrated. In this attempted correlation of mechanical properties, the eutectic cell size is of considerable importance, and it is concluded that the weakening influence of the graphite in cast iron is determined by a factor related to the eutectic cell size. Relationships between strength and structure are determined primarily by the eutectic cell size, and secondarily by the graphite size.

Closely allied to the preceding investigation is an intensive study which is being made of the form of the stress/strain curve for the grey cast irons with the object of obtaining more information on the mechanism of deformation, and also to test the validity of theories on the anelasticity of cast iron put forward by Continental

Battery of furnaces for growth testing at low temperatures.

High-frequency electric melting units of 10, 5, 2 and 1 cwt. capacity.

workers. An exhaustive survey on the stress/strain properties and the mechanism of failure of cast iron has already appeared.

Recent work on the fatigue properties of cast iron has concerned the influence of understressing on the fatigue properties of pearlitic and ferritic flake graphite and nodular graphite cast irons. Fatigue tests on these materials previously understressed for 20 million cycles at a stress 0·5 ton/sq. in. below the fatigue limit, showed that understressing produced no appreciable change in the fatigue limit. These results were somewhat unexpected in view of increases in fatigue limit in excess of 30% due to understressing reported by other investigators, though the inconsistency may be due to a difference in structure.

A comparison of the tensile and fatigue properties of as-cast and normalized pearlitic nodular irons (1·63–2·56% silicon) showed that normalizing increased proof stress, tensile strength and hardness, and gave improved elongation in the tensile test. The improvement in the properties obtained depends on the rate of cooling in air after treatment, and also, to a small extent, on the normalizing temperature used. It was found that normalizing, which gives a marked increase in tensile properties, does not give a correspondingly marked increase in fatigue properties.

Graphite Formation

The theory developed to explain the structure of ordinary grey iron in terms of eutectic cell size and number has already been mentioned. Work is in hand to test this theory and experiments have begun on the influence of inoculation and superheating on eutectic cell number and mechanical properties.

White Cast Irons

Investigations on white cast irons are proceeding under three headings :

(1) *Factors Influencing the Chilling Tendency of Cast Iron.*—This investigation includes a study of the influence of casting size and chill size ; the effect of degree of nucleation of the melt on chill depth and mottle spread ; and a study of the mechanism of mottle formation by means of thermal analysis.

(2) *Factors Influencing the Structure of White Cast Iron.*—This includes an examination of the solidification mechanism of cast iron by means of cooling curve and quenching studies, and an investigation of microstructure and undercooling during solidification in relation to melting temperature.

(3) *Hot Tearing of White Cast Iron.*—This is an investigation of the factors controlling hot tearing, and the incidence of the defect in a number of foundries is under investigation.

Malleable Cast Iron

Specially constructed continuous weighing balances have been installed which indicate the loss of carbon during the decarburization reaction, and these are being used to compare the rate of carbon removal for white iron and pre-graphitized irons. It has been shown that sulphur has a considerable influence. It is often found that relatively thin sections of unannealed malleable castings solidify grey while the heavier sections solidify white or mottled, and the mechanism of this phenomenon of " inverse greyness " is being investigated.

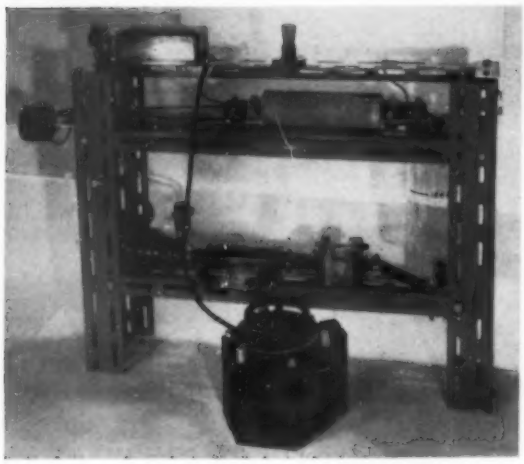
An attempt is being made to overcome the difficulties associated with the production of sound malleable cast iron test bars, and variations in test bar design and methods of running and feeding are being studied in co-operation with certain member firms.

Ingot Moulds

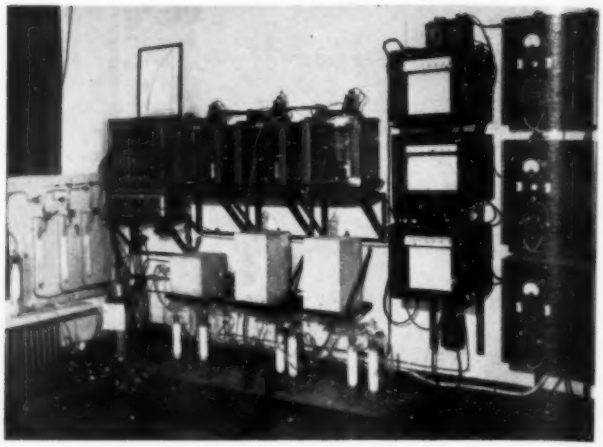
The causes of premature mould failure are under continuous investigation in association with the manufacturers of ingot moulds and bottom plates. Minor investigations are also being undertaken on thermal shock and mould soundness. Some of the work is being carried out in co-operation with the British Iron and Steel Research Association.

Corrosion

Work continues in the form of field tests to study the possibilities of cathodic protection to prevent severe



Anti-freeze corrosion apparatus.



Continuous weighing balances used to indicate carbon loss during the decarburization reaction in the production of malleable cast iron.

pitting attack in cast iron marine propellers. This work has the support of the British Shipbuilding Research Association. Another feature of the work on corrosion is an investigation of the mechanism of accelerated corrosion in cast iron diesel waterways, believed to be due to certain anti-freeze solutions.

Dephosphorization

Possibilities of producing low phosphorus foundry irons using only native resources continue to be investigated. Large scale trials of the oxygen top blowing process are now to be carried out, together with large scale tests to investigate carburization and siliconization.

Gases in Cast Iron

The influence of metal composition and mould conditions on hydrogen pick-up from green sand moulds and the influence of traces of aluminium, magnesium, bismuth and tellurium are being studied with reference to the occurrence of pinholing in grey and nodular cast iron. An attempt is being made to trace the origin of blister gases during enamelling, and the evolution of gases during heat-treatment cycles similar to those used for enamelling is being studied by heating small samples in a stream of argon and then measuring the gases evolved.

The influence of hydrogen on the graphitization of malleable iron is being studied with particular reference to the hydrogen content of the iron before annealing and the hydrogen content of the annealing atmosphere. The influence of preliminary heat treatment at 300°–500° C. is also being examined.

The reported effect of oxygen in reducing fluidity has not been confirmed. The influence of oxygen in relation to trace elements is receiving attention.

Methods of Analysis

Much of the work on the improvements of methods of analysis is carried out in co-operation with members of the B.C.I.R.A. Methods of Analysis Sub-Committee. Recent work in the chemical and spectrochemical fields has been particularly concerned with the development of methods for the analysis of cupola and other slags, and work has already appeared on a direct fluoride volumetric method for the determination of alumina in cupola slags. It will be apparent from the work already reported that very small traces of residual elements can have important effects on the properties and structures of cast iron. Methods of analysis to determine the known significant residual elements such as antimony, lead, aluminium and boron are being developed.

Foundry Sands

Work is now actively in hand on the design and construction of a high-frequency oscillator of greater power than the unit so far successfully used for the determination of the load/deformation characteristics of sand at high temperatures. It is hoped that this unit will give an even more rapid heating of the test pieces.

On the CO_2 process, work continues to study the high temperature properties of sodium silicate/sand mixtures and factors influencing the properties of CO_2 process sand, and to examine the possibilities of economy in the use of gas.

Certain properties of green sand are under investigation, involving a study of the factors influencing the properties of bonded sand in the green state, with particular reference to the practical problems of stripping and the ability of sand to conform to the surface irregularities of a pattern in the moulding process.

Development Work

The responsibilities of the Association's Development Department are, of course, chiefly exercised in dealing with the practical day-to-day problems which arise in members' foundries, and this advisory service, which handles about three enquiries per working day, usually entails a visit to the foundry seeking assistance. The Scottish laboratories at Blantyre provide, in miniature, for the benefit of Scottish members, some of the development services available at Alvechurch.

During the course of dealing with enquiries from members, it sometimes happens that a problem or a process is thrown up in relief and requires some special investigation to be carried out. Such investigations are usually of direct practical interest to the foundry and two recent examples may be quoted. The first consisted of an examination of sub-surface blowholes in grey irons occurring in association with manganese sulphide

segregations. This investigation was prompted by the fact that this type of defect was intermittently reported by a number of foundries.

The second investigation was initiated following an examination of five commercially produced castings which failed either before or during service. It was shown that failure was due to the occurrence of abnormal forms of graphite in the structure which could be produced by the presence of very slight amounts of certain elements in cast iron. The work in this instance was directed to elucidating the effect of :

(*a*) tellurium derived from tellurium-bearing mould or core washes, or as an addition to the metal, and,

(*b*) lead arising from the use of lead-bearing materials in the charge.

Although the interfering elements were present in infinitesimal quantities, they were clearly shown to produce abnormal mesh and Widmanstätten graphite structures, which seriously reduce the mechanical strength of the iron in which they are present.

An example of a development investigation centring on a particular process is provided by a recently published account of an exhaustive investigation into the welding of flake graphite cast irons, the methods and metallurgical principles involved, and the mechanical properties of butt-welded joints in these materials. A supplementary investigation arising from this welding programme concerned brittle failure of " bronze " welds, and demonstrated the occurrence of a layer of a hard brittle iron-silicon constituent at the junction of the parent metal and the weld, due to a high silicon content in the filler rod.

The Development Department includes the Foundry Atmospheres Section, whose responsibilities for developing methods of controlling dust in foundry processes are now increased by commitments arising under the Clean Air Act, which requires the control of dust and fume emitted by furnaces to the external atmosphere.

The volume " Foundry Ventilation and Dust Control," which establishes principles for the accurate calculation of the air movement required to control dust clouds produced at a given point in the foundry, was referred to in the last annual review. This work, which covers very fully the formation, dispersal and control of dust in the foundry, has received considerable recognition abroad as well as in the United Kingdom.

During the year a side-draught knock-out hood has been designed on the basic principles developed by the Foundry Atmospheres Section and installed in a fully mechanized foundry in the Midlands. A film has recently been made to illustrate the principles and operation of this knock-out.

The advisory service of the Foundry Atmospheres Section continues to provide guidance on matters connected with dust, fume and grit control, the implementation of foundry regulations, and the suppression of atmospheric pollution. Work has been completed on methods of arresting or suppressing dust and fume in the cupola, and an examination of the amount of sulphur oxides emitted by cupolas has been made.

Proposals are now under consideration to provide a small laboratory block at Alvechurch to give adequate experimental facilities for work on foundry atmospheres. Field investigations will be made on dust arresters used by foundries, and data will be collected for statistical analysis to evaluate the behaviour of various types of equipment in different applications. The results should help to solve the clean air problem and to assist further in providing specifications necessary for dust control within the foundry.

Operational Research Team

The Operational Research Team continues its advisory services to those foundries which are concerned with problems of production efficiency and productivity in general. Since its inception, the Team has made more than 700 visits to over 400 different foundries. In making a survey, considerable importance is attached to production flow lines, and thus particular attention is given to the routing of materials to and from the foundry, and also within the foundry itself. The layout of the site itself is, therefore, involved, and suggestions involving reorganization of the site are usually illustrated in a drawing which accompanies the report embodying the Team's recommendations.

The Team is particularly concerned with handling problems, and hence with the use of mechanized aids and also fully mechanized equipment. At the same time an endeavour is being made to collect as many statistical data as possible from the foundries visited, in the hope that it will be possible eventually to provide some basis for a measurement of efficiency. A report dealing with the performance values for a group of foundries engaged in the production of municipal castings has already been prepared. This gives the output per operative in each of the various sections of the foundry, namely, melting, moulding, core-making and fettling. It is hoped to extend this form of analysis to other types of foundry. An analysis is being made of the utilization of labour in cupola operation, and a detailed examination of plate moulding and snap flask moulding methods is also in hand, the principal object of this work being to establish some yardstick of performance against which foundries may compare individual performance and efficiency.

Intelligence Department and Library

The increased number of research projects, together with the number of enquiries received on members' problems, is reflected in the work of the Intelligence Department, which is also responsible for all the Association's own publications, for dealing with enquiries that can be answered on the basis of published information, and for the organization of exhibitions and conferences.

Producer/User Conference

A new type of conference (at which the total attendance was nearly 300) was inaugurated by the Association in November, 1956, when producers and users of iron castings were invited to meet in London to discuss papers presented by both sides on the properties and suitability of grey iron castings for a range of engineering applications. Technical developments and improved control methods during the last twenty years have greatly increased the potentialities of existing materials and have placed new materials at the disposal of the engineer and designer. Every year nearly 4 million tons of castings are produced in the United Kingdom : even if pipes, ingot moulds, building and domestic castings are excluded from this total, it is clear that about 60% of the production is consumed annually by the engineering industries. Increasingly, in recent years, the Association has been approached by engineers and users for advice on the behaviour of castings under

given conditions of load and stress, and on the suitability of the material for specific applications, or under special conditions of service, for example, wear, corrosion and high temperature.

This conference was an attempt to relate some of the existing knowledge on the properties of the material with the experience of users in different fields, and it may provide a pattern for smaller meetings in the future between producers and users, at which narrower fields of application can be explored in more detail.

To meet the needs of engineers and users, the Association has in preparation a detailed handbook of data on the materials available at the present day.

Award to Director

The B.C.I.R.A. Director, Dr. J. G. Pearce, whose life work has been the promotion of the Association's growth and progress to the leading position amongst research associations which it holds today, was awarded the C.B.E. in the Queen's Birthday Honours List recently published. He was previously awarded (in 1950) the O.B.E. for services to research and industry.

Dr. Pearce has signified a wish to be relieved of his executive responsibilities at the end of 1958, and in anticipation the Council has appointed Mr. H. Morrogh to be Deputy Director and Dr. H. T. Angus to be Assistant Director to Dr. Pearce as from July 1st, 1957. Both Mr. Morrogh and Dr. Angus continue in their respective functions of Research Manager and Development Manager.

Mr. Morrogh, who has been with the Association since 1933, became Research Manager in 1945. His outstanding contributions to the metallurgy of cast iron alloys have earned for him an international reputation in this field. Perhaps the chief of these was the first announcement in 1948 of the discovery of nodular graphite cast iron. These contributions have been recognized by the award of four gold medals by metallurgical institutions: the Andrew Carnegie Medal of the Iron and Steel Institute (1946), the E. J. Fox Medal of the Institute of British Foundrymen (1951), the W. H. McFadden Medal of the American Foundrymen's Society (1952), and the Sir Robert Hadfield Medal of the Iron and Steel Institute (1956).

After graduating at Leeds University in fuel and metallurgy, Dr. Angus subsequently took his M.Sc. and Ph.D. degrees. From 1927–1945 he was Chief Chemist and Metallurgist to the Parkinson Stove Co., Ltd., engaged on the production of vitreous enamelled light castings, steel castings, and a variety of engineering products. He became B.C.I.R.A. Development Manager in 1945, and has been responsible for the expansion of the Development Department, for the section dealing with foundry atmospheres, dust control and ventilation, and for the Scottish Laboratory at Blantyre. He was a member of the Grey Ironfounding Productivity Team which, under the leadership of Mr. S. H. Russell, C.G.I.A., visited the U.S.A. in 1950.

The British Non-Ferrous Metals Research Association

(*Continued from page 182*).

ments have proved unsuitable as a guide to the selection of refractories, the decision was taken to install a 600 lb. Ajax-Wyatt furnace in the Association's own foundry. This furnace is now in operation and trials of various refractory linings are proceeding.

Another research is being carried out on the "rollability" of copper alloys. The Association's own rolling mill has been instrumented to make possible the determination of rolling loads, and experiments have been carried out to determine the relationship between the rolling loads needed to give similar reductions to different copper-base alloys. This will provide the industry with data from which can be derived rolling schedules to enable the best utilisation to be obtained from available plant.

Building Extensions

An expansion of research activities concerned with the traditional non-ferrous metals together with the branching out into the newer metals has resulted in the Association outgrowing its present buildings. The favourable response of members towards an appeal for a special fund for building development allowed a start to be made early this year on extensive reconstruction of existing property to facilitate its better use for laboratory work. In addition, a contract has been placed for a new building to be erected on vacant ground belonging to the Association adjacent to one of the laboratory blocks.

A proportion of this space is already earmarked for the work on thorium and other aspects of the metallurgy of nuclear power, but, in addition, provision is being made for an extension of the existing mechanical testing laboratory, largely to enable extra creep and fatigue testing machines to be installed. The physics laboratory, which is at present working under very cramped conditions, will also be partly re-housed, and the electroplating section will be given a new pilot scale plating shop. The foundry, whose present operations are hampered by the fact that it is on two floor levels, is to be rebuilt and enlarged, and there will also be major re-arrangements of the corrosion section and extensions to the library and information department.

Faster Export Deliveries

To expedite delivery of a consignment of furnaces to Holland, and to economise on costs, Wild-Barfield Electric Furnaces, Ltd., sent the equipment from factory to user by road, the vehicle crossing by ferry from Tilbury. The furnaces, which are large and form part of a new heat treatment installation which includes gas carburising equipment, reached their destination at Eindhoven much more quickly than would have been the case by conventional means of transport—for no transhipment handling was necessary—and more economically as the use of crates and packing materials was obviated.

Another British Oxygen Fellowship

An additional Fellowship for Post-Graduate Research has been awarded by British Oxygen to Mr. R. D. Johnston, B.Sc., A.I.M., for research in the Department of Metallurgy at Battersea College of Technology.

The British Steel Castings Research Association

By A. H. Sully, M.Sc., Ph.D., F.Inst.P., F.I.M.

Director of the Association

Now that the Association is established in its own Research Station, the scope of its experimental work will be widened considerably. Facilities are available for the study of moulding materials, steelmaking, foundry processes, the properties of cast steel, and the operation of foundry plant and equipment. A brief outline of the main lines of investigation being pursued is presented here.

THE year 1957 has marked the completion of an important stage in the development of the British Steel Castings Research Association. During the year the Association's new Research Station in Sheffield was completed and opened: a description of the experimental foundry, laboratories and offices has already appeared in these columns. The Association is now equipped on a scale sufficient to enable a carefully integrated programme of investigational work to be planned covering all aspects of steel foundry processes. Corresponding with the occupation of these new premises there has been a notable increase in the Association's staff, which now totals approximately 50, of whom two-thirds are directly engaged in experimental work.

This article will describe the organisation which has been set up to carry out the research activities, and give an outline, albeit brief, of the main lines of investigation which are being pursued, and of some projects in which significant progress has been made during the past year.

The Association is organised into five principal sections, each under a section head directly responsible to the Director. These sections are :—

(1) Foundry Processes—Section Head: Mr. J. M. Middleton, A.Met., A.I.M.

(2) Plant Engineering—Section Head: Mr. C. M. Stoch, Dipl.Ing., F.I.M.

(3) Steelmaking—Section Head: Mr. T. A. Cosh, B.Sc., A.R.C.S.T., F.I.M.

(4) Metallurgy—Section Head: Mr. W. J. Jackson, M.Sc.(Eng.), A.R.I.C., A.I.M.

(5) Information and Library—Information Officer: Mr. W. E. Fuller.

Foundry Processes

The Foundry Processes Section is responsible for all investigations covering casting processes and factors affecting the quality and soundness of steel castings. The work of this section thus includes a wide range of subjects. Factors affecting the soundness of steel castings, which are included in the immediate programme of work, include a study of the influence of convection currents on the structure and properties of castings, and of the use of mouldable chilling and insulating media to secure directional solidification and to increase the soundness of castings. Factors affecting the surface quality of castings also feature prominently in the work of this section, and attention is being given to the erosion of sand moulds by molten steel, to the friability of green sand moulds on air drying, and to the effect of mould paints and washes in minimising metal penetration and sand burn-on. A fundamental study of the factors affecting the compaction and "flowability" of moulding sands is being undertaken by a bursar supported by the Association and working at Sheffield University under the direction of Professor J. White.

Attention is being given to some of the newer casting processes. Work is actively in progress on the possibility of developing an alternative to resins for the bonding of sand for shell moulding, with the object of eliminating the objectionable surface markings which accompany the casting of low carbon steels in resin-sand shell moulds. Certain aspects of the CO_2 : silicate bonding process are also being examined.

In addition to its programme of research, the Foundry Processes Section is also responsible for the routine evaluation of new clays, resins, oil binders, etc., which are offered to the industry, and is completing a valuable compilation in the form of data sheets of the properties of the many different moulding sands used in steel foundries.

During the past year this section has completed a study of the analogy between the freezing of steel and of stearin wax. Wax has been used for some years in certain foundries to simulate the freezing of steel as an aid in developing the correct feeding technique for castings of complex shape. A systematic investigation has been made of the validity of the analogy, and has involved the casting in both wax and steel of special shapes designed to explore the effect of casting design on the size and distribution of shrinkage cavities. Other factors which have been studied have been the effects of casting temperature, of "alloying" the wax with soluble additions, and of feeding head geometry. The results have shown that the analogy between the freezing of steel and stearin wax is closest if the wax is cast within 2° C. of its melting point. Under these conditions the simulation is reasonably good, as is illustrated by Fig. 1, which shows traces of X-shaped castings cast in steel and in wax at its freezing point. On the whole, however, it is appreciably more difficult to feed a wax casting to soundness than a similar casting in steel, i.e. if a casting in wax can be made sound it will certainly be sound when cast in steel. This investigation has been of considerable value in demonstrating the possibilities and limitations of this technique.

Plant Engineering

The work of this section not only includes studies of the operation of plant and equipment in use in foundries, but also work in the field of industrial health. In the former category the present programme includes studies of processes for sand reclamation. Many steel foundries

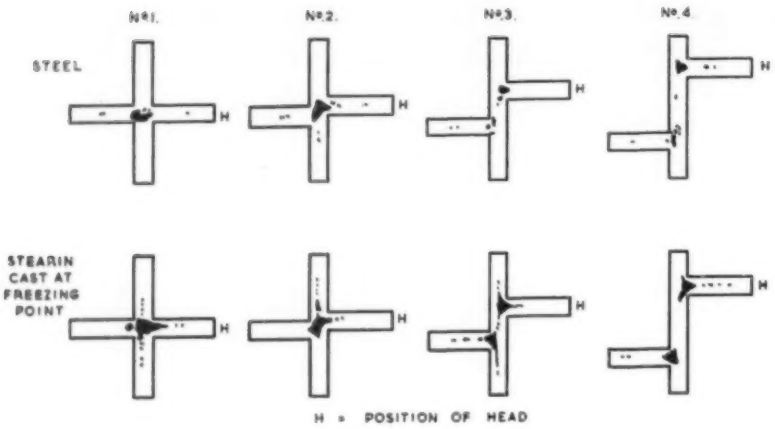


Fig. 1.—Comparison of the shrinkage cavities in stearin wax and steel X-junction castings.

in this country are remote from high-grade deposits of silica sand, and the reclamation of used foundry moulding sands, if this can be achieved economically, is an attractive proposition. During the past year a study has been made of the dry pneumatic scrubbing method, in which the sand grains are cleaned by mutual impact and friction against each other during transference in an air stream. A pilot plant study accompanied by casting trials has helped to define the correct operating conditions for maximum cleaning efficiency. During the coming year a log washer is to be constructed in the Association's experimental foundry, to study in more detail some aspects of wet reclamation processes. Earlier investigations have shown that a simple log washing plant has some promise for this purpose.

Studies are also being made of the performance of moulding machines in compacting sand moulds. These involve not only a consideration of the mechanical characteristics of moulding machines, but also of the effect of variation in the properties of the moulding sand. This work is linked very closely with the more basic study referred to above, which is being conducted at Sheffield University. Certain aspects of this work are illustrated by Fig. 2, which shows traces which have been made of the jolt motion of a jolt-squeeze moulding machine that was recently investigated. It will be seen that, as the air line pressure supplied to the machine is increased from 75 to 78 lb./sq. in., the vibrational wave form alters considerably and the frequency of vibration is markedly decreased. The effect of such variations on mould hardness and casting quality at various points on the surface of moulds with re-entrant pockets is being studied, and will give results which, it is hoped, can be applied to improve the performance of moulding machines.

Other projects in the plant engineering field relate to the efficiency of shot-blast equipment and the influence of composition and shape on the performance of shot, and of chemical methods for removing adhering sand from steel castings.

The Association has for some years pursued an active programme of work in matters pertaining to industrial health, and has successfully developed integral exhaust systems, now being manufactured on a considerable scale, for dust control on swing frame and pedestal grinding machines. Problems of dust control still feature prominently in the investigational programme. Work is in hand on the assessment of dust and on the composition and properties of dust generated in steel foundries. The Association's advice is frequently sought by members in the installation of ventilating and dust control systems in foundries. Work on the biochemical aspects of silicosis, especially with reference to mixed foundry dusts, is supported by the Association at Reading University.

Steelmaking

The new experimental foundry is equipped with a 6-cwt. basic-lined graphite resistor rod furnace, a type of melting unit relatively novel to the steel founding industry in this country, and an assessment is being made of factors affecting its performance and its possible role in foundries as an alternative to high-frequency furnaces. This furnace is also being used for a comprehensive study of factors affecting oxygen injection in

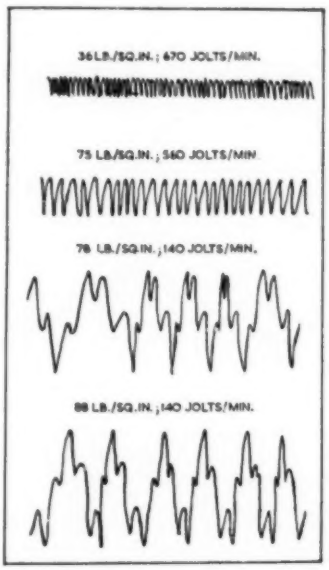


Fig. 2.—Traces of the jolt motion of a simultaneous jolt squeeze moulding machine showing the change in amplitude and frequency of vibration that occurs when the air-line pressure falls below 78 lb./sq. in.

basic electric steelmaking practice. This will be combined with a study of fume emission from the furnace during the period of oxygen injection.

Further studies are being made, both in the Research Station and in members' foundries, of the efficiency of gas flushing processes for the removal of gases from liquid steel.

Physical Metallurgy

The metallurgical investigations of the Association include several long range projects of considerable interest. Prominent among these is a study of the causation and the effect of micro-porosity in steel castings. Dispersed porosity on a very fine scale sometimes occurs in internal regions of castings, and an attempt is being made to discover to what extent this finely dispersed porosity is due to interdendritic micro-shrinkage, and to what extent it is due to the evolution of dissolved gas in the last stage of solidification. The detection of this very fine micro-porosity is a matter of some difficulty, and several techniques, including the attenuation of ultrasonic waves, have been investigated as possible indices of this type of porosity. Ductility is a sensitive index, though only qualitative in character, as is illustrated by Fig. 3, which shows the variations of density and of ductility in specimens taken across the section of an ingot shaped casting. It will be seen that the ductility decreases from the outside to the centre of the section in both positions, but that this decrease is much less marked at the bottom of the casting. The density, on the other hand, shows no such smooth variation across the section and, towards the bottom of the casting, does not even show a minimum at the centre where feeding during solidification is known to be more difficult than at the surface of the casting. Although the reason for the apparently anomalous variation of density is not clearly understood, it appears obvious that ductility shows a much better correlation with the known facts about the distribution of finely dispersed unsoundness in castings.

The metallurgical work also includes a study of the effect of rare earths and other complex deoxidants on the properties of cast steels. Particular attention is being paid to their effect on low temperature impact properties, since steel castings are being required on an increasing scale to operate at sub-zero temperatures.

A comprehensive study is also being made of some features of the heat treatment of cast steels. Little systematic work on this subject has been carried out, and it is proposed to determine the heat treatments that are necessary to obtain the optimum mechanical proper-

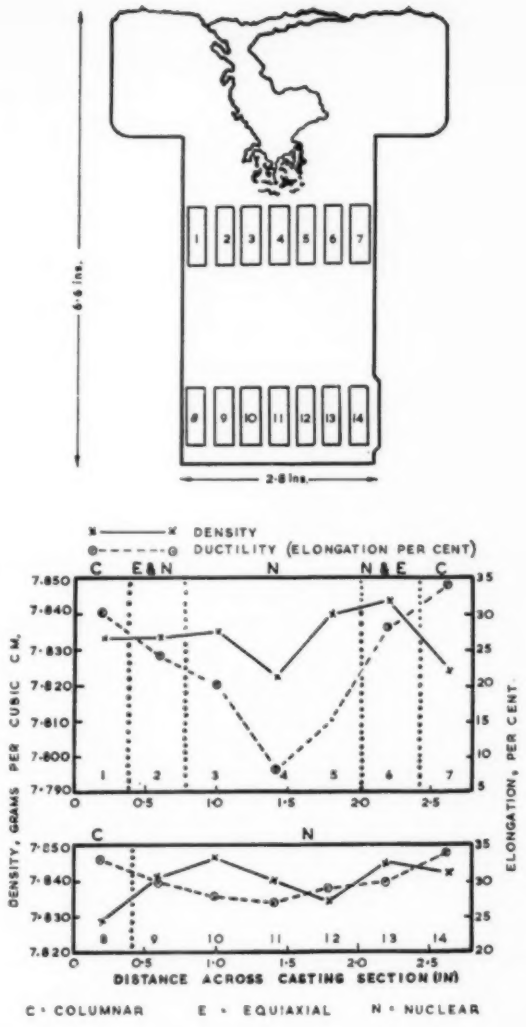


Fig. 3.—Variations in ductility and density in specimens cut from positions near the top and bottom of an ingot-shaped test block, indicated at the top of the illustration.

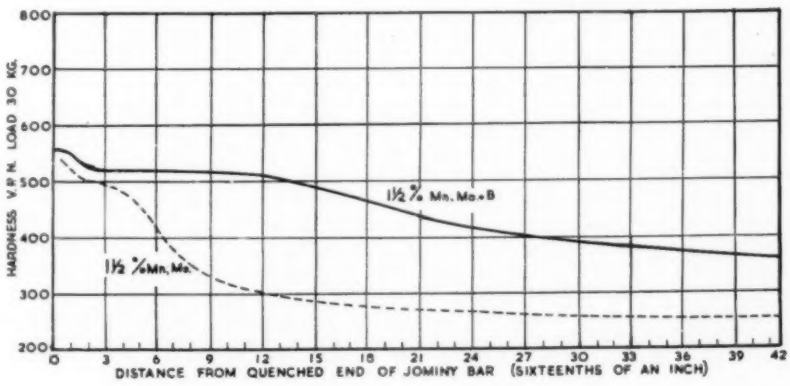


Fig. 4.—Illustrating the marked effect of boron in improving the hardenability of a 1½% Mn-Mo steel.

TABLE I.—REPRESENTATIVE MAGNETIZATION VALUES, COMPARING THOSE RESULTING FROM DIFFERENT FURNACING TREATMENTS WITH EXPECTED VALUES GIVEN IN B.S.1617

Flux Density (B) (gauss)	Magnetizing Field (H) (oersted)					
	B.S.1617		New Heat Treatment Procedure	F.C. to 300° C. (annealed)	F.C. to 700° C. and A.C.	A.C. from 950° C. (nor'zed)
	Grade A	Grade B				
10,000	8	10	5·7	6·2	7·7	9·5
14,000	20	28	16·5	19·0	22·0	35·5
15,000	30	40	25·0	29·0	31·0	63·0
17,000	85	110	70·0	78·0	81·0	—
18,000	—	—	120·0	133·0	128·0	—

F.C.—Furnace Cooled. A.C.—Air Cooled

ties with maximum economy, especially in steels of thick section prone to interdendritic segregation.

Investigations substantially completed in the recent past include a study of the effect of heat treatment on the magnetic properties of cast low carbon steel, and this has resulted in the development of a heat-treatment procedure which not only produces magnetic properties superior to those attained by full annealing, but also does this with an economy in furnace time. The improvement to be obtained by this method is illustrated by the data given in Table I.

The effect of boron on the hardenability of cast steels of various compositions has also been studied. Fig. 4 shows the marked effect of boron in improving the hardenability of a 1½% manganese-molybdenum steel. The curves shown are standard Jominy end-quench curves, in which the Vickers hardness is plotted as a function of the distance from the quenched end of the bar.

Library and Information Section

The increased scale of the Association's activities has been accompanied by a considerable and still growing use of the Information Services by the staff of member firms. Apart from the Association's bi-monthly publication *B.S.C.R.A. Abstracts*, bibliographies on special subjects and translations from foreign literature are frequently issued to members. A close integration exists between the Information and Research Sections in dealing with technical enquiries from members. Liaison visits to members are normally made by senior members of the research staff, the Association's ability to spare technical staff for this purpose being determined largely by the compactness of the steelfounding industry. There is no doubt that, as a consequence of this increasing liaison activity, as well as the acquisition of vastly improved facilities for experimental work, contact between the Research Association and the industry is very close, and is to the mutual advantage of both.

Personal News

(*Continued from page 162*)

A. P. V. Paramount, Ltd., the stainless and alloy steel founders of Crawley. Mr. McLelland, will also be acting in an advisory capacity in technical matters. His home address will be 29 Davison Avenue, Whitley Bay.

MR. D. HALL, has joined Low Moor Alloy Steelworks, Ltd., and Yorkshire Rolling Mills, Ltd., as General Works Manager.

DR. L. G. GROVES has been appointed Managing Director of Davy British Oxygen, Ltd., from September 5th, 1957, and relinquishes his appointment on the Board of British Oxygen Wimpey, Ltd.

MR. G. M. WOLFE, Joint Managing Director of Wolf Electric Tools, Ltd., set out in mid September on a three months global business tour which embraces Canada, New Zealand, Australia, Malaya, Thailand and India.

MR. V. H. F. HOPKINS has been appointed Manager of Engineering, Diesel Engine Division, of the English Electric Co., Ltd., directly responsible to the General Manager, MR. A. V. WILKIN.

Obituary

We regret to record the death of the following :—

DR. R. W. BAILEY, F.R.S., formerly of the Metropolitan-Vickers Electrical Company's Research Department, who died on September 4th. Dr. Bailey first joined the Company as a college apprentice in 1907 and, after a period as lecturer at the Battersea Polytechnic and as Principal of the Crewe Technical Institute, returned to it 1919 to take charge of those sections of the Research Department which were concerned with chemical, mechanical and metallurgical problems. He relinquished executive duties in 1945 to devote more attention to special research and development work, and to act as Consulting Research Engineer, from which position he retired at the end of March.

Dr. Bailey was particularly interested in the behaviour and properties of metals at elevated temperatures and their influence on design, and for his published work in this field he was awarded the degree of D.Sc. (Eng.) by London University in 1936. He was also awarded the Thomas Hawksley Premium in 1929 and the Thomas Hawksley Gold Medal in 1935 by the Institution of Mechanical Engineers, in which he took an active interest, rising to the Presidency in 1954. In 1949 he was elected a Fellow of the Royal Society, and was made an Honorary Associate of the Manchester College of Technology in 1950.

MR. GERALD STEEL, C.B.E., General Managing Director of The United Steel Cos., Ltd., and President-elect of the British Iron and Steel Federation for 1957, who died at his Wimbledon home on September 13th at the age of 63. Mr. Steel had been actively associated with the iron and steel industry since 1919, when he joined the Steel, Peech and Tozer branch of the then newly-formed United Steel group. He went to India in 1928 to form The United Steel Companies (India), Ltd., being appointed Managing Director of the new company. He returned to this country in 1932 to become a Director and General Manager of Samuel Fox and Co., Ltd. He was appointed a Director of United Steel in 1941 and then successively Assistant Managing Director, Joint Managing Director, Managing Director, and finally, General Managing Director in 1954.

As President-elect of the British Iron and Steel Federation, Mr. Steel was a member of its Council and Executive Committee and also served on the British Steel Producers' Conference. He was Chairman of the Central Council of Iron and Steel Employers Associations and a Vice-President of the Iron and Steel Institute. Keenly interested in industrial education, Mr. Steel played a prominent part in the formation of the Federation's Training Committee, of which he was the first Chairman.

Réaumur—Pioneer Metallurgist and Scientist

By M. Schofield, M.A., B.Sc., F.R.I.C.

Réaumur, who had a wide range of interests in scientific subjects, was one of the few men of his time who sought to make known improvements in the science of metals and their application. He was invited by the Academy of Sciences to investigate industrial problems in an attempt to improve the poor record of France, and in so doing contributed to many developments in the metallurgical field.

THE 200th anniversary of the death of Réaumur on October 17th is an occasion for reviewing the scientific contributions of this eminent Frenchman, particularly in such applied aspects as the development of the iron and steel industry, in which France had fallen far behind British and Swedish producers. René Antoine Ferchault de Réaumur, who was in his voluminous *Mémoires* as long-winded as his name, might be called an "encyclopaedic spirit," since he sought to cover every point in the manner of classic encyclopaedists. But although his interests were so wide, he was no jack-of-all-trades. Even if his single plunge into industrial management brought financial failure as director of "Le Manufacture Royale d'Orleans pour Convertir le Fer en Acier at pour Faire des Ouvrages de Fer et d'Acier Fondus," this failure does not detract from the many advances he brought or the essential principles he included in his writings. Réaumur should be appreciated today as one of few who sought to make known improvements in the science of metals and their applications, rather than seek to maintain secrecy. He was a worthy successor to Agricola and to Ercker, who wrote on metallurgy in the 16th century, leaving for posterity a vast volume of papers from which one may piece together the essentials.

Wide Range of Interests

Before and after Réaumur's remarkable decade from 1716 to 1726, during which period he studied iron and steel and then suddenly turned his attentions elsewhere from the metallurgical field, he was a scientist, both pure and applied, of very wide interests. He would probably have remained pure scientist had not France, through the medium of the Academy of Sciences, called upon him to direct investigations into industrial problems in attempts to improve the poor record of France in times when imported Swedish iron was superior, while French steel was well below the standard of the English product. Réaumur was an aristocrat intended for law in his education; yet soon he was turning to philosophy and science, first to mathematics, physics and biology.

Born in 1683 at La Rochelle, he arrived at the age of twenty in Paris, to attract attention very quickly with his first three memoirs on geometry, together with an early delving into physics in a study of wave motion, and with biological studies also appearing. At his Charenton home in suburban Paris he had his laboratory and science collections, his household staff including laboratory assistants. It is relevant to mention his rôle as biologist if only to serve as reminder that, whereas one view holds Réaumur's many papers on iron and steel to form his chief work, workers engaged in pure science consider his six-volume memoirs on the history of insects to be his most important work bequeathed to posterity. In biology he had his small zoo and aviary, studied electric eels or torpedo fish, and wrote exact minute observations on the lower animals. His studies of creatures like the mayfly and the caddis worm became such classics, unexcelled today, that it is no wonder there is the claim that his iron and steel contributions were of less importance than his pure science. One certain point is that his bicentenary should be an occasion for banishing the view that Réaumur's thermometer-making and his thermometric scale, in which his name is still perpetuated in school textbooks, were of great importance. Using alcohol in preference to mercury as thermometric fluid, with bulbs of up to 4½ in. in diameter and graduated by use of a pipette, Réaumur designed his thermometer with each increment representing a definite fraction of the volume at the freezing-point—the only fixed point he defined. With his thermometer obsolete it seems no more appropriate to perpetuate the name of Réaumur in this way than in the name of a station on the Paris Metro railway. While on the subject of physics it may be recalled that Réaumur was very much in touch with Mussenbroek of Leyden in the development of the Leyden jar and in work on electric discharges. He contributed papers on animal digestion, on geology and marine biology.

Tinplate and Cast Iron

But now to the applied science of Réaumur and to metallurgy, to the harvest forthcoming when the Academy of Science charged him with the direction of "les divers Arts et Métiers" in order to improve French industry. Among his many memoirs in answer to this call, we hear of studies dealing with the turquoise mines of France, with auriferous rivers, with the preparation of paper from wood pulp, with an "opaque glass" as substitute for the porcelains of Saxony and Japan, with the strength of fibre glass, and with tinplate production. The latter in particular is noteworthy, since Réaumur's recommendations became standard practice for centuries to come. There is also the curious story of Réaumur going to acquire secrets of the German tinplate trade, a story given in 1774 in the "Universal Magazine of Knowledge and Pleasure" published in London. In an account of "Methods of making Tin-plate, or what is commonly known by the name of Tin, and of which the common Utensils are made," the anonymous author

goes on to describe Réaumur dressing himself " in the mean habit of a peasant and hiring himself as a labourer " and thus learning the essentials for success in the German trade. Réaumur was concerned with the magnetic oxide or " particular kind of rust " which iron sheets acquired " from the fire " and which was not readily removed by the pickling methods of those days. So his plan was to substitute a layer of rust more easily removed by use of vinegar or sal ammoniac solution. When he observed a form of black suet or fat used, he experimented and found that it was not intentionally blackened with soot but was overheated or " burned " for better results. If Réaumur did succeed in acquiring some technique from German tinplate interests, it was probably of little import. It seems to be an essential theme of every advance in some industries to have had " a spy in the factory " at some point in the story ; the spy so often being that old fiddler shivering in the winter night, being brought by compassionate workmen to warm himself before the furnace or kiln, and there to take in at a glance an entire metallurgical technique !

Turning now to Réaumur's classic, his " L'Art de Convertir le Fer Forge en Acier et L'Art d'adoucir le Fer Fondu," a long memoir dedicated to the patron Duke of Orleans, and having as sub-title the " Art of Producing Cast-iron Work with the Finish of Wrought Iron," it must be emphasised that the work must be judged in the light of what metallurgy and chemistry was known in the period 1716–26. It was a handicap to be studying constituents of cast-iron a whole century or more before sulphur was established as an element. There were no testing devices available ; indeed Réaumur had to measure hardness by observing scratchability with various minerals, and as a result forecast a scale of hardness. He made the first testing-machine when measuring the deflection of a bar of heat-treated steel before fracture. Réaumur suffered much criticism ; for since he enabled iron articles to be produced at a twentieth of the original cost, the idea of " cheapness " was not generally liked. He was deemed too discursive or long-winded by some readers, while Voltaire even accused him of copying foreign methods, of being simply " a good observer." Voltaire also condemned Réaumur for being even more academic than English craftsmen held him to be : " You can add in a second edition of the article on Iron " wrote Voltaire to the editors, " that all those who wished to manufacture cast-iron according to Réaumur's methods have been ruined." Yet only Réaumur tried to combine a scientific basis with the empirical ideas of the craftsmen of the period.

Structure of Metals

Réaumur's interest in heat led in turn to furnaces, and to the essential air for combustion, though he postulated that air must be excluded in cementation. He pointed out that metals could not be heated beyond their boiling-points, while in his drawings he attempted to picture for the first time the structures of metals. Though Réaumur only had a hand-lens to study fractures, his many plates in the memoir showing fractures of different kinds of iron and steel are classics in the history of metallography. He referred to grain and to intergranular fracture, and wrote of " salts and sulphurs " causing changes on heat-treatment by becoming rejected from voids and even being forced outside the steel itself.

In addition to the somewhat alchemical reference to " salts and sulphurs," he wrote of " earth " (now silicon) being present in grey cast-iron in higher proportion than in white iron. He noted that with a hard white iron it is easier to obtain a ductile product after malleablisation, observed the effect of small inclusions of sulphur, and saw how the rate of cooling played some part in determining fracture types. Though he knew that hot iron formed scale in air and used charcoal to pack round it, he had not understood decarburisation. While Descartes believed that the hardness of steel was due to clusters of " particles " being more uniformly dispersed at higher temperatures, Réaumur went on to hint at interstitial constituents migrating by diffusion and then becoming frozen by sudden cooling. He foresaw that details of formation and heat treatment of steel would be explained by use of chemical solution and segregation beyond what is betrayed by fracture examination.

Réaumur was awarded a pension of 12,000 livres as reward for his endeavours in this field, yet he returned the monetary award to be used by Academy members in furthering the study of industrial topics of benefit to France.

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B.C.I.R.A. Orders Hot Blast Cupola

An important order received by the Engineering Division of Newton Chambers & Co., Ltd , Thorncliffe, near Sheffield, from the British Cast Iron Research Association is for an experimental hot blast cupola installation at Alvechurch, near Birmingham This will incorporate the Inka radiant type air pre-heater for which Newton Chambers have recently concluded a licence agreement with Industriekemiska Aktiebolaget of Stockholm. The pre-heater is capable of working at higher temperatures than the needle type convection pre-heaters which have been made at Thorncliffe for many years, and will enable the Company to extend its range in the field of heat exchangers.

The contract with the B.C.I.R.A. was negotiated by Newton Chambers jointly with Constructional Engineering Co., Ltd., of Birmingham, who will be responsible for the installation of the cupola and certain other ancillary equipment. The Association requires this installation for research into more efficient methods of melting, and the conclusions reached will be of benefit to the iron foundry industry in general.

Canadian Blower Order for B.T.H.

British Thomson-Houston has received a contract valued at nearly £100,000 for the largest blast furnace turbo-blower supplied by the Company for installation overseas. The order, which also includes condensing plant, is for the Algoma Steel Corporation of Canada and was received through British Thomson-Houston Co. (Canada) Ltd., of Toronto. The plant is normally rated at 85,000 cu. ft./min., 30 lb./sq. in. gauge, but will be capable of dealing with the maximum volume of 100,000 cu. ft./min. at a discharge pressure of 20 lb./sq. in. gauge. The machine, which will be made in the B.T.H. Rugby Works, will be equipped with the most modern form of volume regulation and anti-surging controls.

Malvern Radio Telescope

Reflector Fabricated in Aluminium Alloy

IN January, 1956, the Royal Radar Establishment at Malvern commissioned a 45 ft. diameter paraboloid reflector to be used for general extra-terrestrial observations and for advanced research in microwave propagation; it was to replace an existing 25 ft. one mounted on a fully steerable turning gear. While it was appreciated that the larger reflector would weigh more, a careful check by the Establishment of the stresses involved showed that a maximum weight of 4 tons could be allowed.

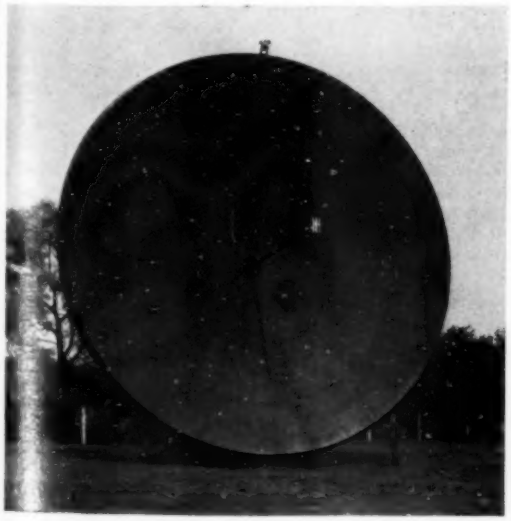
Operating Conditions

The operating conditions specified, under which the reflector had to maintain its true paraboloid shape within the allowed tolerance, were as follows:—

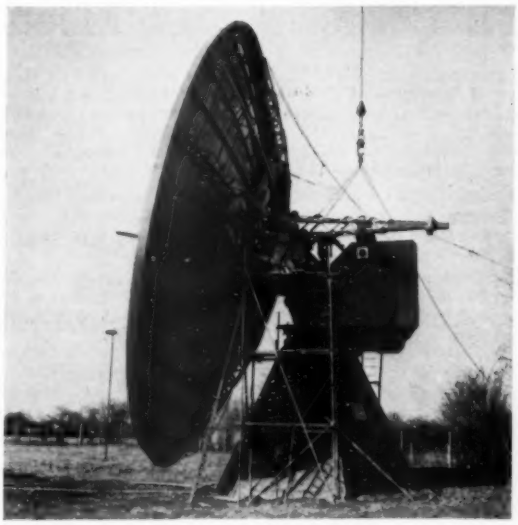
(1) The reflector to be capable of turning through 360° in the horizontal axis and 180° in the vertical; normal astronomical equipment would maintain it on its object.

(2) Accuracy to be maintained in any position; at ambient temperatures from 4° C. to 25° C.; with temperature differentials across the surface, due to part shadowing, of up to 35° C.; at relative humidities up to 100%; and in steady winds up to 30 m.p.h.

(3) The reflector to be capable of withstanding steady winds of up to 60 m.p.h. from any direction, with gusts of 10 seconds duration up to 110 m.p.h.; deposition of up to 2 in. of ice or 12 in. of snow on all upward-facing surfaces; all without damage, vibrations, resonances, permanent deformation, or failure of any kind. Incidentally, although these conditions were initially considered difficult with a reflector of this size, similar ones are now under construction by Precision Metal Spinnings designed to operate in maximum winds of 90 m.p.h. and to withstand gusts of up to 150 m.p.h.; and projects are under consideration for reflectors up to 150 ft. in diameter.



General view of the completed telescope.



Fixing counterweights to the reflector.

The reflector was designed jointly by the Engineering Department of the Establishment, by Precision Metal Spinnings (Stratford-on-Avon), Ltd., and by Messrs. Jenkins & Potter, who acted as consultants; general advice was also given by the Aluminium Development Association, and advice on riveting by Dr. Whiteman, of the Military Engineering Experimental Establishment, Christchurch. The reflector was fabricated and erected by Precision Metal Spinnings.

Method of Construction

Two alternative methods of construction were suggested:—

(1) A welded mesh surface of $1\frac{1}{2} \times 1\frac{1}{2}$ in. squares in 14 s.w.g. wire, with a tolerance under all operating conditions of $\pm$ 1 in. from true paraboloid.

(2) A continuous sheet metal surface, with a tolerance under all operating conditions of $\pm \frac{1}{4}$ in. from true paraboloid; this in effect gave manufacturing tolerances varying from $\pm \frac{1}{16}$ in. at the centre, to $\pm \frac{1}{8}$ in. towards the periphery, these closer tolerances being required to allow for any possible deflection under the worst operating conditions.

This second alternative method of construction was preferred by the Establishment; the weight limitation and the need for minimum maintenance made aluminium the obvious choice for the surface skin and for the whole reflector structure, except for the bearing trunnions,

which are of mild steel. British Standard aluminium alloy H10-WP was used, which was supplied by the British Aluminium Co., Ltd.; all joints were riveted. All the aluminium was treated with etch primer, and an iron oxide undercoat; finishing coats were green on the back of the assembly, and matt black on the reflecting surface. Particular attention was paid to bimetallic joints between aluminium alloy and steel, the mild steel being aluminium-sprayed before assembly.

The radio telescope was ready for use in April, 1957, the project from conception to completion having taken some sixteen months.

Meeting Diary

2nd October

Royal Institute of Chemistry (Manchester and District Section), Chemical Society and Society of Chemical Industry. Conjoint Meeting. Symposium: "The Newer Metals (Zirconium, Hafnium, Beryllium, Niobium)." The University, Manchester. 2.30 p.m.

Institute of British Foundrymen, Southampton Section. "Thoughts on the Development of the CO_2 Process," by A. TALBOT. Technical College, St. Mary's Street, Southampton. 7.30 p.m.

Institution of Production Engineers Preston Section. "The Production of Nuclear Fuels for the Atomic Power Programme," by DR. J. E. LITTLECHILD. Harris College of Further Education, Corporation Street, Preston. 7.30 p.m.

3rd October

Institute of Metal Finishing (North West Branch). "Plastic and Metal Spraying," by K. MARSH. Engineers' Club, Albert Square, Manchester. 7.30 p.m.

8th October

Institute of British Foundrymen, Slough Section. "The Know-how of the CO_2 Process"—Brains Trust, with DR. D. V. ATTERTON, J. L. RICE, A. TALBOT and A. P. LOVAT. Lecture Theatre, High Duty Alloys, Ltd., Slough. 7.30 p.m.

9th October

Institute of Welding (Manchester and District Branch). "Welding—The Modern Solution of Engineering Problems," by E. FUCHS and R. PARTRIDGE. Reynolds Hall, College of Science and Technology, Manchester. 7.15 p.m.

Manchester Metallurgical Society. Presidential Address. DR. K. M. ENTWISTLE. Manchester Room, Central Library, Manchester. 6.30 p.m.

Society of Chemical Industry, Corrosion Group. "The Corrosion Resistance of Titanium," by J. B. COTTON and H. BRADLEY. 14 Belgrave Square, London, S.W.1. 6.30 p.m.

10th October

Incorporated Plant Engineers, North East Branch. "The Manufacture of Tubes," by H. B. ELLIOT. Roadway House, Oxford Street, Newcastle upon Tyne. 7 p.m.

Liverpool Metallurgical Society. Presidential Address by J. S. W. GRAHAM. Liverpool Engineering Society, The Temple, Dale Street, Liverpool. 7 p.m.

Institute of British Foundrymen, Beds. and Herts. Section. Presidential Evening, arranged by the new President, MR. G. SMITH. K. and L. Steelfounders and Engineers, Ltd., Letchworth. 7.30 p.m.

East Midlands Metallurgical Society. Presidential Address by N. S. ANGUS. Nottingham and District Technical College, Shakespeare Street, Nottingham. 7.30 p.m.

15th October

Birmingham College of Technology Metallurgical Society. Presidential Address by DR. I. G. SLATER, followed by a Technical Film Show. College of Technology, Birmingham 6.30 p.m.

Institution of Production Engineers, Tees-Side Section. "Heavy Forging," by R. C. BENSON. The College of Further Education, Cleveland Avenue, Darlington. 7 p.m.

16th October

Institute of Fuel (North Western Section). "Sludge and Scale Control in Low-Pressure Boilers," by DR. J. A. GRAY, E. F. THURSTON and L. FURNIVAL. Engineers' Club, Albert Square, Manchester. 2.30 p.m.

Institute of Welding (Manchester and District Branch). "Craftsmen Welders." Film and Discussion. Municipal Technical College, Bolton. 7.15 p.m.

Institution of Production Engineers, Birmingham Section. "The Technique of Tube Making," by L. C. HACKETT. James Watt Memorial Institute, Great Charles Street, Birmingham. 7 p.m.

Institution of Production Engineers, Wolverhampton Section. "Practical Research into Machining Problems," by J. CHERRY. Wolverhampton College of Technology, Wulfruna Street, Wolverhampton. 7.15 p.m.

17th October

Institution of Mining and Metallurgy. "Control of Air Pressure as an Aid to Fight Mine Fires," by J. M. CAW; and "The Production of Zinc in a Blast Furnace," by S. W. K. MORGAN. Geological Society, Burlington House, Piccadilly, London, W.1. 5 p.m. (Tea served from 4.30 p.m.)

21st October

Institution of Production Engineers, Coventry Section. "Russian Machine Tool Industry" (Some impressions of a recent study made in Russia), by N. STUBBS, M.B.E., and P. TRIPPE. Craven Arms, High Street, Coventry. 7.15 p.m.

Institution of Production Engineers, Sheffield Graduate Section. Practical Lecture: "Drop Stamping and Forging." Daniel Doncaster & Sons, Ltd., Penistone Road, Sheffield, 6. 6.30 p.m.

23rd October

Manchester Metallurgical Society. "Early Metallurgy," by PROF. F. C. THOMPSON. Manchester Room, Central Library, Manchester. 6.30 p.m.

Institute of British Foundrymen, London Branch. "Aids to Automation," by J. A. HUFTON. Constitutional Club, Northumberland Avenue, London, W.C.2. 7.30 p.m.

Institution of Production Engineers, Worcester Section. "High Speed Presswork," by J. A. GRAINGER. Cadena Cafe, Worcester. 7.30 p.m.

25th October

Manchester Association of Engineers. "Brittle Fracture," by G. M. BOYD. Engineers' Club, Albert Square, Manchester. 6.45 p.m.

North East Metallurgical Society. "Metals used in the Jewellery and Silverware Industry," by MISS D. PILE. Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough. 7.15 p.m.

Royal Institute of Chemistry (Manchester and District Section). Dalton Lecture. "Coal and Coal Chemistry in the National Economy," by DR. J. BRONOWSKI. Town Hall, Manchester. 7 p.m.

29th October

Institution of Production Engineers, Oxford Section. "Properties of Pure Molybdenum Disulphide and its Application to Production Engineering," by H. P. JOST. North Oxfordshire Technical College, Banbury. 7.30 p.m.

31st October

Institution of Production Engineers. The 1957 Sir Alfred Herbert Paper: "The Bases of Measurement," by DR. H. BARRELL. Royal Institution, Albemarle Street, London, W.1. 6.30 p.m. (Tea will be served from 5.30 p.m.). By ticket only, application for which should be made to The Secretary, Institution of Production Engineers, 10 Chesterfield Street, London, W.1.

NEWS AND ANNOUNCEMENTS

School of Welding Technology

SINCE 1948, the Summer School of Welding organised by the British Welding Research Association at Ashorne Hill, has provided each year a one week study course under the guidance of experts in various aspects of welding. Each year demand has greatly outrun the accommodation, showing that the engineering industry recognises the need to keep its key men up-to-date in the rapidly developing field of welding technology. Further evidence has been provided by the overwhelming response of the Institute of Welding's course of evening lectures on the detail design of welded structural steelwork.

As the outcome of discussions between the Institute and the Research Association, it has been decided that the Summer School shall be discontinued, and that the Institute will set up a School of Welding Technology, active throughout the year and providing short, intensive courses, each dealing with a selected aspect of welding, or the application of welding in a single section of engineering production. Enrolments will not exceed forty for any one course, but, over the year, the School will be able to accommodate about a third more students than can be taken at Ashorne Hill.

The courses are intended for technologists with industrial experience and responsibility. Students will be assumed to have the education of an engineer and at least a basic knowledge of the various welding processes and their use in industry. Lecturers, drawn mainly from leading experts in industry, will describe the present state of knowledge in their subjects, and each course will include, beside surveys of the best contemporary practice, an account by a member of the British Welding Research Association's staff of the latest developments and trends in research.

Conference on Problems of Aircraft Production

THE Sixth Annual Conference on Problems of Aircraft Production, promoted by the Southampton Section of the Institution of Production Engineers, will again be held at the University of Southampton on January 2nd and 3rd, 1958, when the theme will be, "U.S. and U.K. Practice." The Conference will be opened by the presentation of the Third Lord Sempill Paper, which will be given by MR. BOYD K. BUCEY, Assistant to Vice-President—Manufacturing, The Boeing Airplane Co. Further details of the programme will be announced shortly.

Industrial Film Festival

A FESTIVAL of Films in the Service of Industry is to be held in Harrogate, October 8th to 12th. The RT. HON. LORD GODBER is President, and invitations to be Vice-Presidents have been accepted by THE EARL OF HALSBURY THE RT. HON. VISCOUNT CHANDOS, D.S.O., M.C., THE LORD MACKINTOSH OF HALIFAX, D.L., LL.D., THE LORD BAILLIEU, K.C.B., C.M.G., THE LORD HEYWORTH, and SIR ALEXANDER FLECK, K.B.E., F.R.S., D.Sc.

Sponsors and producers of films made for industrial purposes have been approached to submit films for consideration by the selection panels, which will make a selection to go forward for competitive exhibition at the Harrogate Festival. The panels are made up of representatives of the film industry and the various industrial organisations interested in specific aspects of the use of film in industry.

For the first year the competitive element is confined to films produced in this country, but invitations have been sent to European and Commonwealth countries, the U.S.A. and many others, asking them to nominate their best films in the various categories for exhibition only at the Festival. The following countries have agreed to send films—France, U.S.A., Canada, New Zealand and Pakistan.

Pulverised Fuel Conference

THE Second Conference on Pulverised Fuel organised by the Institute of Fuel will be held at the Institution of Civil Engineers, Great George Street, Westminster, S.W.1, on Wednesday and Thursday, 27th and 28th November, 1957; there will be morning (10–12-30) and afternoon (2-30–4-45) sessions on both days. The general purpose of the Conference will be to bring up to date a review of developments in pulverised fuel firing since the Conference at Harrogate in June 1947, and to set the subject in focus against the general background of development in all fuels, including nuclear-fuels. After an opening paper by DR. G. H. DANIEL, Under-Secretary, Ministry of Power, on "Energy Supplies in the U.K. and Overseas—with special reference to Pulverised Fuel Practice," the first two sessions will deal with fundamental and applied research on pulverised fuel. The third and fourth sessions will be devoted to "Practice in the U.K." and "Practice Overseas in Australia, France and Belgium, Germany, and the U.S.A.

Non-Ferrous Mining Symposium

THE Institution of Mining and Metallurgy and the United Kingdom Metal Mining Association are to hold a Symposium in London during September, 1958, on "The Future of Non-Ferrous Mining in Great Britain and Ireland." It is proposed to discuss the known and prospective occurrences of minerals other than iron and coal in Great Britain and Ireland, and the problems, both technical and economic, affecting their exploration and development.

Papers have been promised on the economic geology of the mineralized areas, on the working of existing non-ferrous metal mines, and on mineral rights, mining taxation, and metal prices. Further particulars will be announced later this year.

Newton Chambers Welding Approval

NEWTON CHAMBERS & CO., LTD., have been placed on the Lloyds Register of Shipping Approved List of makers of Class I fusion welded pressure vessels. This is part of a pattern of progress and development which is creating a widening range of activity and an increasing capacity in the workshops of the Engineering Division at Thorncliffe.

The Heavy Constructional Shop extension recently completed was planned to increase output capacity by 50% and to provide for new engineering developments. Among equipment installations introduced here were modern facilities for welding to Class I requirements, for automatic welding of pressure and other vessels and for heavier plate fabrications.

In the Engineering Division's Development Department, also recently completed, where all development activities are being centralised, important work is in progress on heat exchange equipment for high temperatures and special conditions. Class I welding is required not only for these developments, however. Pressure vessels for the atomic power industry require the highest possible standards of welding. The petroleum, chemical, and oil industries are also making growing demands, and into all these fields Newton Chambers are extending their activities.

New British Oxygen Welding School at Birmingham

A NEW welding school recently opened by British Oxygen Gases, Ltd., will provide welding and cutting instruction for employees of industrial firms in the Birmingham area. It has permanent accommodation for nine students of gas welding, and two argon welding students. Included in its programme will be pipe welding courses of six weeks' duration, and general courses in both welding and maintenance. Gas welding and cutting blowpipes, straight line and profile cutting machines, and argon equipment have been installed. There are also facilities for lectures and film shows. Students come not only from the district, but also from abroad, entries having been received from Nigeria and the Sudan. A recent visitor was the Principal of the Technical College of Barbados, who intends sending students to the new building.

Plastic Coated Steel Sheet

JOHN SUMMERS & SONS, LTD., in co-operation with B.X. Plastics, Ltd., are now producing commercially a new type of coated steel sheet with the trade name Stelvetite. It is a cold reduced strip mill product with a specially formulated Velbex P.V.C. coating. The P.V.C. is 0·014 in. thick and can be supplied in almost any colour. It is resistant to acids, alkalis, greases and detergents, and has excellent abrasion resistance. Its electrical properties are good and an important feature is that it is warm to the touch compared with uncoated steel. There is little doubt that the potential industrial applications for this material are very wide, particularly as it can be bent, formed and deep drawn without damage to the coating.

Low Carbon Steel Annealing Symposium

DR. A. R. TROIANO, Professor and Head of the Metallurgical Department at Case Institute of Technology, will direct the concentrated, two-day International Symposium on the Annealing of Low Carbon Steel to be held at Case, October 29th and 30th. The symposium is a co-operative effort on the part of the Lee Wilson Engineering Co., Inc. and Case, and invitations have been issued to 150 of the top steel specialists in 17 countries throughout the world. Experts from six nations will deliver a dozen papers on annealing processes during the five general sessions, which will be conducted by chairmen selected from the highest ranks of the profession. Following the International Symposium at Case, many of the visiting metallurgists will journey on to Chicago for the Second World Metallurgical Congress.

World Metallurgical Congress

OFFICIAL recognition of the 2nd World Metallurgical Congress and a welcome to the more than 500 overseas metal scientists from 40 nations planning to attend it, was enacted by the Congress of the United States late in August, according to Dr. Zay Jeffries, Director General of the Metal Congress.

A congressional Resolution, H. J. 404, was introduced first to the House of Representatives by Congresswoman Mrs. Frances P. Bolton, 22nd District of Ohio, and then to the Senate by John W. Bricker, Senator from Ohio.

The Resolution points out that " the United States has a responsibility and an opportunity to provide vigorous leadership in the search for substitutes for critical resources." It further states that metal scientists are " contributing actively to the mastery of new wonder metals and the peace-time use of the atom." The U.S. Congress requests the President " by proclamation, or in such a manner as he may deem proper, to grant recognition to the World Metallurgical Congress and the American Society for Metals," says Dr. Jeffries.

The World Metals Congress, to be held at Chicago, November 2nd-8th, 1957, at Hotel Sherman, is sponsored by the American Society for Metals. The attendance will be in excess of 45,000.

Plant Engineers Refresher Course

THE Rt. Hon. Lord Sinclair, K.C.B., K.B.E., Pro Chancellor of the University of Bristol, Past-President of the Federation of British Industries, and Chairman of The Imperial Tobacco Company (of Great Britain and Ireland) Ltd., is sponsoring the comprehensive refresher course for senior works and plant engineers which is to be held at Bristol University this winter. Organised by the Education Committee of Incorporated Plant Engineers, in collaboration with leading industrialists and technical authorities, it comprises 19 weekly lectures on Tuesday evenings commencing October 15th. The fee for the course is four guineas, and copies of the syllabus and full particulars may be obtained from the Secretary to the Refresher Course, University Engineering Laboratories, University Walk, Bristol 8 (tel. 24161).

Government Copper Disposal

THE Board of Trade announced on August 20th that they intended to dispose of 27,000 tons of copper from the Government stockpile, but that none would be offered for sale before October, 1957. The Board have since announced that, in view of the disturbed state of the copper market, they have decided not to offer any of this copper for sale for the time being. The position will be reviewed towards the end of this year.

Change of Telephone Number

AN additional exchange line has been connected at Swansea Branch Office of British Insulated Callender's Cables, Ltd., and the telephone numbers are now Swansea 52094 and 54403

RECENT DEVELOPMENTS

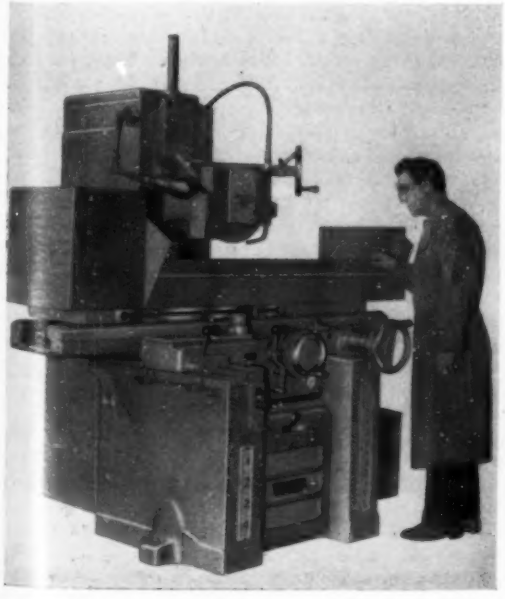
MATERIALS : PROCESSES : EQUIPMENT

Surface Grinders

A NEW line of hydraulic precision surface grinders, Hydrabrasive Nos. 824, 1218 and 1224, feature a big capacity, a new spindle design, a new design eliminating heat generally encountered with hydraulic powered machine tools, and a new cross-feed saddle adjustment. The sizes of the three machines are 8 × 24 × 12 in., 12 × 18 × 12 in., and 12 × 24 × 12 in., respectively. All standard Hydrabrasive models have 12 in. of grinding clearance to the table under a 12 in. wheel, but they can be built with 18 in. under a 12 in. wheel. Also, 24 in. models can be safely extended to 30 in. in length without sacrificing strength or accuracy.

For trouble-free operation, the Hydrabrasive spindles are cool running, and lifetime sealed lubricated : they have anti-friction preloaded bearings. Spindles are precision ground and are powered by special "soft" running motors. All components are Dynetrically balanced after assembly, and to eliminate any possibility of binding on the column ways, the head and spindle assembly is balanced on the elevating screw.

The Hydrabrasives have two hydraulic cylinder rams to actuate the table, each ram being under pressure only half of the time, and resting and cooling the other half. Oil cushions absorb all shock at the end of each stroke, and the fact that the ram is the piston, eliminates old-fashioned out-of-line piston rods. The hydraulic system is low pressure, is small, compact and simple, and is easily removed for inspection or maintenance. The entire power unit is cooled by a large volume air flow, the coolant system being located outside of the machine, so as to eliminate heat transfer from that source.



For highly accurate transverse saddle adjustment, Hydrabrasives have a precision ground cross-feed screw with backlash eliminator and ball bearing saddle ways. The saddle moves on $\frac{3}{4}$ in. steel pre-loaded ball bearings on hardened steel square ways. The hydraulic motor turns the screw for rapid saddle transverse when dressing the wheel.

All controls are conveniently grouped for natural, effortless operation, and are mechanically interlocked for positive safety. The elevating hand wheel is located on the head because it eliminates back breaking crouching to line up work. Each control is engineered to allow the operator to work in a natural, comfortable position during each operation.

Abrasive Machine Tool Co., Dexter Road, East Providence, Rhode Island, U.S.A.

Small Mobile Loading Shovel

WHILST a great many bulk handling problems outside the factory have been satisfactorily solved in recent times, there still remains the occasional bulk handling problem inside the works of which limitation of space or other similar consideration prevents a simple solution. To meet the requirements presented by such conditions F. E. Weatherill, Ltd., have developed the S.I type mobile industrial loading shovel.

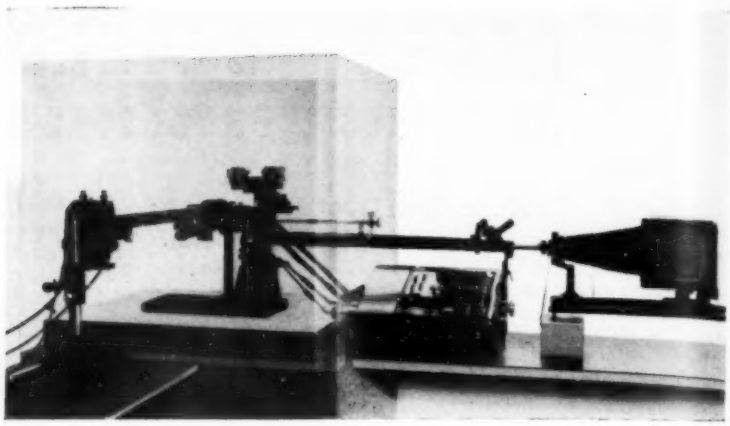
This miniature loading shovel can get almost anywhere, as it is only 4 ft. 6 in. wide with a wheel base of as little as 4 ft. 9 in. It is highly manoeuvrable and, whilst it can be operated under a ceiling of as little as 6 ft. 3 in. (190 cm.), the machine has the unprecedented advantage of an exceptionally good forward reach, together with a discharge height that is more than adequate to load tipper and other trucks of usual type. The lifting capacity is 10 cwt. and a range of scoops is available to accommodate the handling of a wide variety of materials. Operator comfort and safety has received special attention, and a unique offset seating arrangement is provided which, together with the interesting single boom arrangement successfully avoids the necessity of seating the driver between moving parts. Specialised versions of the basic design have already been supplied to meet the individual requirements of users in the foundry and glue and wharfinger industries.

F. E. Weatherill, Ltd., Welwyn Garden City, Herts.

Material Handling Pump

THE present day practice in this country is to buy finishing materials in bulk containers, and to transfer the material to other containers for use in the shop. Logical practice is to use the material straight from the bulk containers, and paint manufacturers are now prepared to supply their paints at controlled viscosity ready for use. To meet this need for equipment, and enable paint to be used straight from the drum, Alfred Bullows & Sons, Ltd., now offer a suitable pump.

This is the Model 41–8500 Bullows-Binks material



handling pump, which can supply paint to a gun or guns straight from the container to a dead-end system for non-pigmented materials, or to a circulating system where the materials to be handled may settle out in the lines. It will provide a steady flow of material to be delivered at a high rate with a long, smooth pump stroke, giving delivery on both the up and down movements. Low maintenance cost and long life are assured by very low operating speeds.

Depending on the application, the unit is suitable for supplying material to at least six spray guns over a medium size circulating system, providing that pipe sizes are adequate. Again, depending upon the type of material in use, it has a delivery pressure up to 150 lb./sq. in., for a main line air pressure of 80 lb./sq. in. Air consumption is ½–1 cu. ft./min./gal., and the pump will empty a full 55 gal. drum of SAE 20 oil in less than five minutes. The pressure control is built in by which the material pressure may be set as required and the pump will automatically compensate for line variation, ensuring that as additional guns are turned on, extra material is delivered to maintain the specified main line pressure.

Alfred Bullows & Sons, Ltd., Long Street, Walsall, Staffs.

Remote Control Microscope

PROGRESS in the peaceful use of atomic energy is dependent on the solution of a multitude of metallurgical problems, and microscopes capable of being used for the examination of radioactive materials will, therefore, play an important role. The Reichert-Shandon remote control metallurgical microscope is claimed to be the first instrument of its kind commercially available. It represents the result of several years development work which was initiated by A.E.R.E., Harwell, on whose suggestions and designs the final version is largely based.

This new instrument is a specialised and considerably modified version of the Reichert universal camera microscope, whose compact design and relatively small size greatly facilitates shielding and remote control. Moreover, the design of the phase contrast, micro-hardness testing and dark field equipment enables these techniques to be applied in quick succession without removing the specimen or altering the set up of the instrument. In order to solve the two-fold problem of illuminating and observing the specimen from positions outside the shielding, special tubular optical devices called "transport optics" have been introduced. In the illustration, with the shielding replaced by Perspex, two of these "transport optics" can be seen—the left-hand one for illuminating the specimen, and the right-hand one for visual microscopy or photo-micrography, at a distance of 30 in. from the centre of the microscope.

All remote controls are centred at the observer's position, to the right of the shielding, with the exception of the objective changer, the operating rods of the compensator slide and the dark field stop, which are mounted to the front of the shielding. Six objectives are mounted in dovetail slots in a magazine in front of the microscope, and are transferred to the universal illuminator over an intermediate bridge by means of a push-pull rod. An additional operating rod is provided for the remote controlled clamping of the micro-hardness tester.

To the right of the shielding, and immediately in front of the observer, is the main remote control station. This accommodates signal lamps to indicate the appropriate coarse focussing positions of the six objectives and the micro-hardness tester; the centre position of fine focus; the position limits of the mechanical stage; and the position of the objective change control rods. There are also controls for the illumination system, and for the electrically driven movements for traversing and rotating the mechanical specimen stage. Additionally, to make operation of the microscope as convenient as possible, a number of mechanical controls terminate in the main control box. These concern coarse and fine focussing, the coarse focus locking lever, the aperture iris diaphragm, the field iris diaphragm, the deviating prism for oblique illumination, and the insertion and withdrawal of the annular diaphragm for phase contrast.

The light source may be a twin-lamp unit, a carbon arc lamp, or a zirconium arc lamp. The twin lamp unit combines a super-pressure 200 watt mercury vapour lamp and a 30-watt low-voltage filament lamp on a swivil bracket enabling instantaneous changeover of illumination.

The optical bench of 1 m. length provided on the right side of the shielding will accommodate, according to requirements, a 13 × 18 cm. mirror reflex camera with

90 cm. bellows (standard); or a 16 mm. Bolex cine camera with Reichert Kinekonnex attachment; or a television camera. There is also available the Reichert 35 mm. attachment camera with lateral focussing telescope.

Shandon Scientific Co., Ltd., 6 Cromwell Place, London, S.W.7.

A New Radiographic Unit

THE Raymax 50 has been developed by Newton Victor, Ltd., to meet the demand for an instrument capable of producing very "soft" radiation, so that minute changes in the density of the specimen will be clearly shown. This is achieved by the use of a beryllium window in the X-ray tube transmitting a high intensity of soft radiation when the tube is energised at voltages as low as 5 kVp. As such radiation is readily absorbed and scattered by air, the X-ray tube has a fine focus, permitting the use of short focus film distances without the sacrifice of fine detail.

The Raymax 50 is suitable for micro radiography, as the fine focus and stepless kilovoltage control enable sharply defined very high contrast pictures to be produced, which can then be photographically enlarged. Other applications include the examination of postage stamps, documents suspected of having been forged, old paintings, and grain for infestation. Although infested grain shows only slight changes in density from that of sound grain, nevertheless, infested grains can be seen quite easily on the radiographs. This versatile equipment has also been used with great success for checking spot welded joints in thin gauge aluminium, and for the checking of low density plastic mouldings for porosity and voids.

The Raymax 50 consists of a transformer, tubehead, and control box. The tubehead, which includes an H.V. transformer and a filament transformer, is fitted with an X-ray tube having a beryllium window; the complete assembly is mounted in an oil-filled container. The control unit includes a kilovoltmeter and continuously variable kilovoltage control, 0–15 milliameter, filament control, and a filament stabilizer maintaining voltage supplied to the filament constant within ± 1%. A synchronous motor exposure timer with indicating lamp is rated from 1 to 55 seconds in steps of one second. The control unit, which is fitted with a carrying handle, can be fixed to a wall or stood on a bench.

For some applications it is convenient to mount the tubehead on a small lead lined cabinet. In other cases a simple tube mounting stand, as illustrated, is suitable.

Newton Victor, Ltd., 132, Long Acre, London, W.C.2.

Floatless Liquid Level Control

A NEW floatless liquid level control is now available for a wide range of industrial applications where it is necessary to control the level of liquid in boilers, tanks, or other vessels. The level control has been designed for use in conjunction with electrically driven pumps and incorporates the Teddington patented liquid level switch.

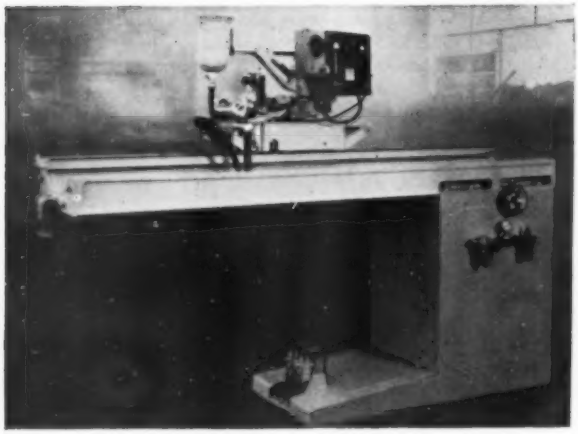
The principle on which the design is based is that heat is dissipated more rapidly through liquid than through air or vapour. The liquid level control switch comprises two probes, each consisting of an Invar rod in a brass tube. The Invar rod is connected to the brass tube at one end, the other remaining free. The thermal expansion of Invar, is very small compared with that of brass, and use is made of this differential expansion in the operation of the control. The Invar rods bear on either end of a pivoted switch lever. One of the rods has a small electrical heater, which is continuously heated, wound around it so that one probe is always hotter than the other. The other probe works in opposition to compensate for changes in the ambient temperature. When the probes are immersed in liquid, the heat is dissipated very rapidly, and the difference in temperature between the two probes is not sufficient to operate the switch. When the level falls, however, and the probes are no longer immersed in liquid, the heat is dissipated at a much slower rate. This increases the difference in temperature between the two probes, causing the switch to close the pump circuit.

Meynell & Sons, Ltd., are at present manufacturing two models, one of which, the Mark III WX/AD/1, is suitable for controlling the water level of steam boilers having a maximum steam working pressure of 120 p.s.i., and for controlling non-corrosive fluids at or near atmospheric temperature at a maximum working pressure of 350 p.s.i. The switch will operate in 8–12 seconds of level change, and the level control covers a wide temperature range from just above freezing point (provided freezing point is not lower than — 22° F.) to 350° F. The Mark III WX/AE/1 is available for operation where a rapid restoration of level is not considered essential or is not required at all. The switch in this case will operate in 32–38 seconds of level change. This model is not suitable for use where the maximum temperature exceeds 250° F.

Meynell & Sons, Ltd., Montrose Street, Wolverhampton, Staffs.

Finger Type Backing Bar Jig

A NEW finger type backing bar jig, designed to facilitate the welding of longitudinal seams in material thicknesses ranging from 0·015 to 0·1 in. has been introduced by Quasi-Arc, Ltd. The clamping of the component edges is effected by means of multiple fingers on to a backing bar mounted on a cantilever mandrel. The clamping fingers, actuated by compressed air inflated hoses operat-



ing at pressures up to 50 lb./sq. in. and giving a clamping pressure of 100 lb./in. on either side, are controlled by foot-operated valves, and each row of fingers can be regulated individually, or together, by means of a reducing valve and air pressure gauge mounted on the machine.

The finger assembly beams are cantilevered from a vertical support which houses the counterbalance spring for the backing bar mandrel. The mandrel is therefore, easily manipulated for loading and unloading the jig. The jig carries a track along one side for a self-propelled carriage and welding head, but may also incorporate a side beam carriage or lead-screw traverse attachment if desired. The jig is designed for floor mounting, through foundation bolts, and provision is made for mounting the welding head control unit on the vertical support.

Quasi-Arc, Ltd., Bilston, Staffs.

Metallizing Gun Accessory

A NEW economy accessory has been recently introduced by Metallizing Equipment Co., Ltd., for their metallizing guns in semi-continuous or automatic use. The unit consists of a small pneumatic cylinder and piston, taking the place of the existing wire feed pressure screw, which enables the wire-feed to be stopped and restarted at will. By eliminating the wastage of wire during periods when the metal spraying gun is not directed at the workpiece, a considerable saving can be made. Some users report savings up to 40% of wire consumption. Additionally, time can be saved by stopping the wire feed during these "down" periods instead of the normal practice of continually switching off the gun and then relighting.

In operation, the piston exerts pressure on the wire-feed rolls in the normal manner. A spring loaded, non-return device prevents the wire from being accidentally withdrawn from the nozzle when the air pressure is released, but can be overridden, when necessary, for changing the wire being used. The unit consumes a negligible amount of air and is supplied complete, ready to mount directly in place of the upper drive roll carrier assembly. No modification to the existing metallizing gun is necessary.

Many types of control valve may be fitted depending upon the intended service. For semi-continuous operation where the metallizing gun is hand held, a remote, foot-operated valve can be incorporated, in which case, pressure on the pedal will immediately feed the wire until the foot pedal is released. On automatic production applications a solenoid or cam operated valve can be made to start the wire feeding as the feed mechanism of the machine is started, or as the piece to be sprayed is indexed. Any number of guns can be operated from one control valve.

Metallizing Equipment Co., Ltd., Chobham, Woking, Surrey.

Argonarc Cutting Process for Aluminium

A NEW method for the cutting and profiling of aluminium has been introduced by British Oxygen Gases, Ltd. Known as the Argonarc cutting process, it enables aluminium plates 1 in. in thickness to be cut at very high speeds using either oxygen-free nitrogen or other gases.

The arc cutting action is produced by a constricted arc of a high temperature and velocity being struck between a tungsten electrode and the surface of the metal and surrounded by a shielding gas. The concentrated and columnated energy of the arc stream melts and ejects a thin section of metal to form a kerf. The result is a clean cut edge with little or no adhering dross. A power source giving an open circuit voltage of at least 110 volts enables arc voltages of 66-80 to be obtained at various current settings.

The strength and lightness of aluminium make it the ideal metal for ships' decking and superstructures, for the construction of vessels, and for applications in the atomic energy field. With the increasing use of aluminium, the advantages of the new process are expected to prove of considerable value to industry at the present time.

British Oxygen Gases, Ltd., Spencer House, St. James's Place, S.W.1.

CURRENT LITERATURE

Book Notices

IRON AND STEEL INDUSTRY IN EUROPE

Report prepared by the Iron and Steel Committee of the Organization for European Economic Co-operation. 93 pp., including 47 tables. Obtainable from H.M. Stationery Office, 10s.

ALTHOUGH this Report is on much the same lines as that published by the O.E.E.C. last year, it contains a more detailed study of matters relating to manpower and productivity, as well as a new section, which deals first with trade between the E.C.S.C. countries, and secondly with trade between the O.E.E.C. and non-O.E.E.C. countries. In the conclusions, particular attention is given to the current problems of the European iron and steel industry.

Under the stimulus of very keen demand, the iron and steel productions of the O.E.E.C. countries in 1956 were 6·5% and 7% higher than in 1955, being respectively 60 and 83 million tons. As last year, the index of crude steel production is still higher than the index of industrial production.

Raw material supplies have not, in general, caused any great difficulty. It is, however, made clear that the results have only been obtained at the cost of larger imports of coking fines, scrap, and ore from non-O.E.E.C. countries, these coming mainly from the American continent. In view of the difficulty in obtaining scrap, still further efforts are needed to increase steel production by using a higher proportion of pig iron. Generally speaking, raw material prices have risen.

The Report then discusses the pattern and structure of investments. It notes that there has been a general increase in capital investment, not only for renewing and extending existing plants, but also to comply with the current tendency to build new production units. It also stresses the fact that more attention is now being given than in previous years to stages before the rolling mills, mainly coking plant, preparation of burdens, and iron and steel making capacity.

An examination of the labour situation reveals a slight increase in employment, difficulty in recruiting skilled and unskilled men, a fairly general tendency for wages to rise and for official working hours to be reduced. The Report points out that in these circumstances output only increased as a result of higher productivity, and that efforts in this respect must be continued.

In concluding the chapter on production, the Report draws attention to the rise in production costs; it considers that the possibilities of raising output on the same costs basis have been exhausted.

The chapter on demand, which deals with the situation of individual countries, states that demand has retained the healthy and non-speculative character which was a feature of the previous year, and is still expanding, despite some falling off due partly to certain anti-inflationary measures, or to shortage of manpower in the consumer industries. The main feature of trade is a considerable rise in exports to non-O.E.E.C. countries: imports from those countries, though remaining at a high level, are still, as previously, purely complementary to other supplies. The prices of iron and steel products are also discussed by the Committee. Since 1954 there has been a rising trend, but there is a disparity between export prices (which, being directly subject to the fluctuations and pressure of demand, follow the general upward trend) and domestic prices, which in aggregate only rose slightly and were sometimes checked by anti-inflationary measures.

The Committee concludes by listing the main problems of the iron and steel industry in the O.E.E.C. countries. It must reduce the dependence of the O.E.E.C. area on non-O.E.E.C. countries (improvement in the pig iron/steel ratio and better coke resources may contribute to this), solve the manpower difficulty, pass on the rise in production costs to the consumer, and improve the conditions for financing investment, which must be maintained at a high level. The Report ends with the following cautionary statement: "Prospects of expansion in the consumption of steel are generally considered favourable, but this does not rule out the possibility of fluctuations in the economic situation, or even of local recessions due to anti-inflationary measures."

THE BRAZING OF ALUMINIUM AND ITS ALLOYS

Information Bulletin No. 22, published by The Aluminium Development Association, 33 Grosvenor Street, London, W.1. 36 pp., numerous illustrations. 2s.

BRAZING is now an established method of joining aluminium and its alloys, giving for many applications both economic and technical advantages over other metals. The Ministry of Supply has now approved a specified brazing process for many classes of work.

The Bulletin opens with a brief comparison of the principal methods of brazing—flame, furnace, and flux dip—and then deals with the basic principles, including an essential note on the operation of capillary flow. The properties of aluminium and some of the alloys suitable for brazing are tabulated and corresponding data are given for aluminium filler alloys, together with notes on the extremely useful form of clad brazing sheet. Preliminary notes to the operations proper include information on fluxes, references to joint design, and notes on preparation for brazing, on fluxing, and on stopping-off.

The different brazing procedures of flame, furnace and flux dip brazing are then described, and these are followed by notes on flux removal and the finishing of brazed components. The choice of brazing method is then dealt with in the light of the preceding descriptions, after which the properties of brazed joints are briefly discussed. The Bulletin concludes with information on the brazing of aluminium to other metals.

BEHAVIOUR OF METALS AT ELEVATED TEMPERATURES

Published for The Institution of Metallurgists by Iliffe & Sons, Ltd. 122 pages, including 63 diagrams in the text and 3 pages of art plates. 21s. net (postage 8d.).

SINCE 1947 the Institution of Metallurgists has held a Refresher Course annually for its members. Each year a particular theme is chosen, and papers giving the latest information on the subject are read by leading authorities. Last year, the theme was a very important

one—The Behaviour of Metals at Elevated Temperatures—which description covers the effect of temperatures from only slightly above normal up to the highest working limits. The present volume contains the papers presented.

In the introductory paper, DR. N. P. ALLEN, Superintendent of the Metallurgy Division of the National Physical Laboratory, discusses the effects of high temperatures on the engineering properties of metals, such as stability of physical properties; elastic constants and coefficients of expansion; resistance to plastic deformation and fracture under stress; the behaviour under fluctuating temperatures; and resistance to chemical attack. He also discusses the principles to be followed in developing alloys having good mechanical properties at high temperatures. These principles are illustrated and amplified in the last two papers.

The second paper, by MR. G. E. MEIKLE, of the Metallurgy Department, Ministry of Supply, deals with the effects of temperatures up to 450° C., with particular reference to airframe structures and guided missiles. among other things he discusses kinetic heating, a comparatively new subject which, as speeds increase, will become more important, probably involving a complete change of material from the types in current use.

DR. L. B. PFEIL, Director, Mond Nickel Co., Ltd., deals with the effects of temperatures of 500° C. upwards on non-ferrous metals, and discusses what is being done to provide improved materials for high-temperature service, and finally, MR. W. E. BARDGETT, Research Manager, United Steel Cos., Ltd., deals with high temperature steels, and shows how extended research is leading to a sounder basis for selecting the composition for particular applications.

The papers in the present series, which contain the latest information on a number of important subjects, and a great deal of original material, will prove invaluable not only to metallurgists but also to engineers developing and designing equipment for high temperature operation.

Trade Publications

WE have received from Leybould Vacuum Sales, Ltd., a copy of a brochure (in English) dealing with the Type HVO 12 high vacuum melting furnace made by Degussa-Wolfgang, for whom Leybould are agents. Melting is effected in a water-cooled copper mould and can be carried out in high vacuum or under a protective atmosphere. The furnace is very versatile, and can be used with consumable or non-consumable electrodes. It can be operated with melt capacities up to 2 litres, and even 5 litres with an extra device.

MANY industries produce large quantities of dust during their manufacturing processes. Sometimes this dust is of no value, but in other cases it is a valuable by-product, the collection of which yields a handsome profit. Quite apart from any question of its intrinsic value, dust in the wrong place is most undesirable, as it may affect the health of workers, cause unnecessary wear and tear to machinery, or become a nuisance to surrounding property. The collection of dust is, therefore, a matter of some importance and the subject is featured at some length in a brochure "Modern Dust Collection," issued by The Visco Engineering Co., Ltd., Croydon. As compared with the 1953 issue, the text has been rearranged and slightly modified, and tables of typical dimensions and capacities are now given. The section on fume removal has been omitted, with a view to a separate publication dealing with it, but among the new illustrations is one of a combined dust recovery and fume removal plant whose main features are described.

THE BRITISH ALUMINIUM CO., LTD., have recently issued a catalogue on Imprest aluminium sheet. This sheet has a comparatively shallow impression, most of the designs being highlighted against a matt background. It is essentially a decorative finish and is available in eight standard patterns. Imprest is produced in two qualities. Normal commercial purity (99%) is quite satisfactory for lacquering or for use in the untreated condition, but anodising quality should be used for material which is to be anodically protected. Imprest patterns are normally applied to hard temper material, but half-hard temper may be supplied if extra ductility is needed.

WE have received from George Kent, Ltd., Publication 2021, which deals with the instrumentation and automatic control of soaking pits. The purpose of these pits is to act as a reservoir between melting shop and rolling mill, in which the ingots are heated uniformly to the correct temperature for rolling, and have produced on their surfaces the desired scale formation, which is dependent on the combustion conditions in the pit. For automatic operation, therefore, it is necessary to control both these factors, and Publication 2021 discusses ways by which these requirements can be met.

Books Received

"über die Aushärtung von Aluminium-Kupfer-, Legierungen." By Dr. H. Franz. 156 pp. Düsseldorf 1957. Aluminium-Verlag GmbH.

"La Fonderie d'Aluminium en Sable et en Coquille." By R. Irmann. Preface by R. Gadeau. Translated from the German by J. Moiroud. 321 pp., with numerous illustrations. Paris, 1957. Dunod. 3.900F.

"The Chemistry of Organometallic Compounds." By E. G. Rochow, D. T. Hurd and R. N. Lewis. 344 pp. inc. author and subject indexes. New York and London, 1957. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 68s. net.

"Boron, Calcium, Columbium and Zirconium in Iron and Steel." By R. A. Grange; F. J. Shortsleeve and D. C. Hilty; W. O. Binder; and G. T. Motock and C. M. Offenhauer. 533 pp. inc. name and subject indexes. New York and London, 1957. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 112s. net.

"The Rolling of Strip, Sheet and Plate." By E. C. Larke. Foreword by Dr. Maurice Cook. 404 pp. London, 1957. Chapman & Hall, Ltd. 63s. net.

"Manufacturing Processes." By M. L. Begeman. 4th Edition. 612 pp. inc. numerous illustrations. New York and London, 1957. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 64s. net.

"Typical Microstructures of Cast Metals." Prepared by Sub-Committees T.S.40, T.S.41, and T.S.42 of the Technical Council. 224 pp. inc. index and numerous illustrations. Manchester, 1957. The Institute of British Foundrymen. 21s. to members; 84s. to non-members.

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
OCTOBER, 1957. Vol. LVI, No. 336

The Application of an Intermittent A.C. Arc Unit to the Analysis of Aluminium Alloys

By J. H. Oldfield, F.R.I.C.* and E. A. R. Ferm
Bragg Laboratory, N.O.I.D., Sheffield

The results of the authors' investigations indicate the general utility of the low voltage intermittent A.C. arc for the analysis of aluminium alloys with the minimum amount of sample preparation. The use of a two-step filter ensures that adequate sensitivity for the determination of small concentrations of impurities is combined with a satisfactory order of reproducibility over a wide range of element concentrations.

BEFORE the development of the method discussed in this paper, the quantitative analysis of aluminium alloys was carried out in the Bragg Laboratory by the procedure described by Edwards.[1] This procedure requires the exposure of standards on the same plate as the samples, and the latter have to be re-cast to ensure that their metallurgical condition matches that of the standards, which have been prepared in a similar manner.

The importance of sample preparation is generally recognised[2] and the procedure of preparing specially cast samples usually adopted. The taking of such precautions presents no serious difficulty when a laboratory is concerned with foundry control analysis, since it is then a relatively simple matter to cast a spectrographic sample under the requisite conditions. In an inspection laboratory, however, re-casting of samples is a time consuming factor, and necessitates the provision of a comparatively large amount of material. Consequently, it was often found more economical in the Bragg Laboratory, where small batches of different types of alloys have frequently to be tested, to make a spectrographic assessment of impurities with the D.C. arc globule technique, and complete the analysis by chemical methods.

The D.C. arc was found to be unreliable for even such a limited purpose, however, and it was decided to investigate the use of a low voltage intermittent A.C. arc circuit for this work. The circuit had been originally designed for the analysis of zinc-base alloys,[3] but had been considerably modified to extend the range of excitation conditions available. It had to be borne in mind that a reasonable economy could be effected only if a method were developed which could be applied to the determination of minor constituents and impurities in samples varying considerably in size, shape, and metallurgical condition.

The investigation included the establishment and control of excitation conditions, the selection of line pairs and the use of a two-step filter. This last feature increased the working range of certain line pairs and facilitated the use of the two line pair method of plate calibration.[4]

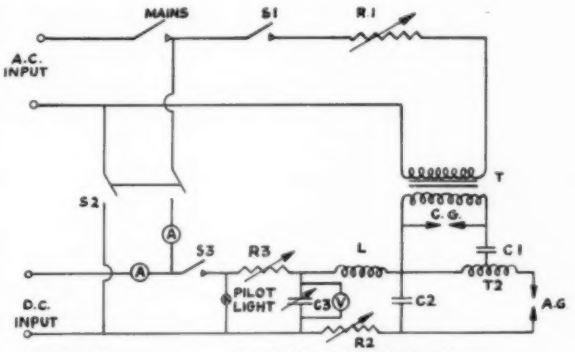


Fig. 1.—Intermittent low-voltage arc circuit.

A Hilger medium dispersion spectrograph and non-recording densitometer were used.

Source Unit

The essential feature of the source unit used is that a low-voltage condenser of high capacity is discharged across the analysis gap by means of a triggering spark. The triggering spark is generated in an independently controlled high-voltage condensed spark circuit, which is coupled to the low-voltage circuit by means of an auto-transformer. By adjusting the parameters of the triggering circuit, the frequency and mode of occurrence of the triggering spark can be controlled. Hence the initiation of the discharge of the low-voltage condenser, which volatilises and excites the sample, is itself controlled.

Referring to Fig. 1, the triggering circuit consists of a resistance *R*1, a high-voltage transformer *T*1, a condenser *C*1, a control gap *C.G.*, and an auto-transformer *T*2. The auto-transformer consists of eight turns of stranded

*Now with the Admiralty Materials Laboratory, Poole, Dorset

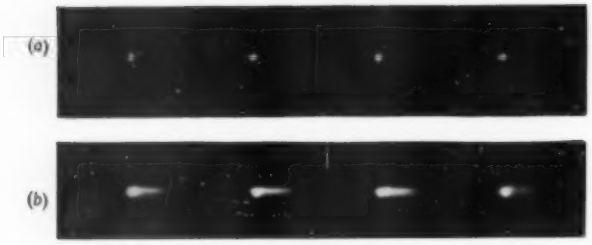


Fig. 2.—Types of discharge obtainable: (a) spark-like; (b) arc-like. The interval between successive discharges is 0.01 second.

rubber-insulated 20 s.w.g. copper wire wound on a wooden former 8 in. square: it is tapped to give an 8 : 1 ratio. It replaces the Tesla coil of the previous circuit,[3] with a consequent reduction in the amount of inductance associated with the low-voltage circuit.

The transformer *T*1 is an old pattern Hilger ¼ kW. unit. The control gap *C.G.* consists of two pure copper electrodes 8 mm. in diameter, supported in an insulating mount which permits careful adjustment of the width of the control gap. It was found that electrodes with flat, roughened ends produced the most reproducible sparking conditions.

The low-voltage excitation circuit consists of a high-frequency choke *L* and high-voltage low-capacity condenser *C*2 which prevent feed back of the high-frequency currents to the mains, a high-capacity low-voltage condenser *C*3, and resistances *R*2 and *R*3. The low-voltage condenser *C*3 consists of twelve condensers each having a capacity of 10 μF. A simple switching device enables a range of 20–120 μF. to be used in steps of 20 μF. The resistance *R*2 controls the rate of discharge of *C*3, and hence modifies the characteristics of the arc.

Types of discharge obtained by varying *R*2 are shown in Fig. 2. In each case a series of discharges is seen, each discharge occurring during one half cycle of the charging current. Fig. 2*a* shows the most "spark-like" discharge, with the minimum value of *R*2; and Fig. 2*b* the most "arc-like" discharge, with *R*2 set to give the maximum resistance. The pilot light serves to indicate when the low-voltage circuit switch *S*3 is closed, and acts as a safety device by ensuring that *C*3 is discharged when *S*3 is opened again. When the A.C. intermittent arc is used, the unit is connected direct to the A.C. mains and the switch *S*2 closed. For intermittent D.C. arc work *S*2 is opened and the direct current obtained from a mercury rectifier giving smoothed full wave rectification. The rectifier is connected at the points indicated.

Although the purpose of the triggering spark is merely to initiate the discharge of *C*3 across the analysis gap *A.G.*, it was found that variations of the nature of the triggering spark resulted in variations in the excitation of the sample. This was in keeping with similar observations made by Walsh.[5]

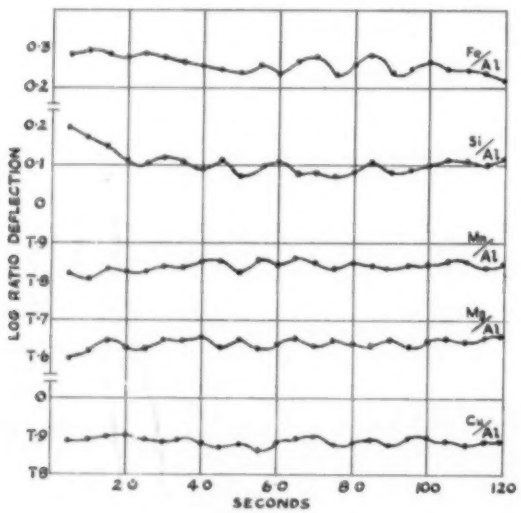


Fig. 3.—Emission curves showing the variation in the line pair ratios over a prolonged period of excitation.

Analytical Procedure

Preliminary tests showed that greater sensitivity and at least a similar order of reproducibility could be obtained for a wide range of element concentrations by using the A.C. rather than the D.C. intermittent arc. Difficulty was experienced in preventing the formation of a continuous arc when currents greater than 3 A. were used. Consequently, subsequent work was directed towards ascertaining the optimum conditions with the intermittent A.C. arc.

Preliminary tests were made on a series of standard duralumin alloys. In all cases the samples were prepared by hand filing, the final surface being obtained with a smooth cut file. The counter electrode was a rod of pure graphite 5 mm. in diameter, and having an 80° conical end, the tip being slightly rounded to minimise the effect of variation in the breakdown of the electrode during the initial period of arcing.

Emission curves showing the variation in the line pair ratios over a prolonged period of excitation were constructed as shown in Fig. 3. These curves were obtained by turning the plate-holder down every 5 sec. during continuous arcing of the sample for 2 min. In order to obtain a suitable density of spectrum line, a B10 plate was used and the light source was placed 20 cm. from the slit. The curves indicate that no improvement in reproducibility could be anticipated by using a pre-sparking period, since the variation of the silicon/aluminium ratio which occurs during the first 30 sec. of arcing was found to be itself reproducible. Further tests confirmed these observations.

It was noted that excitation conditions could be reproduced if the electrical parameters were adjusted by setting the resistances *R*2 and *R*3 to the appropriate values, and then adjusting the width of the control gap until a predetermined voltage was indicated by the voltmeter across the condenser, *C*3.

It was also observed that the log. intensity ratio of the spectrum lines Cu I 2293·8 and Cu II 2294·4 remained constant in duralumin alloys, and was independent of the variation of the concentration of copper. For a given capacity, the ratio of the copper lines served to indicate whether the excitation conditions were satisfactory. It was found, however, that although the Cu I/Cu II ratio could be reproduced with different capacities by varying the other parameters, this was no indication that the ratio of the analysis line pairs had been reproduced.

Owing to the sparsity of lines in the spectra of alu-

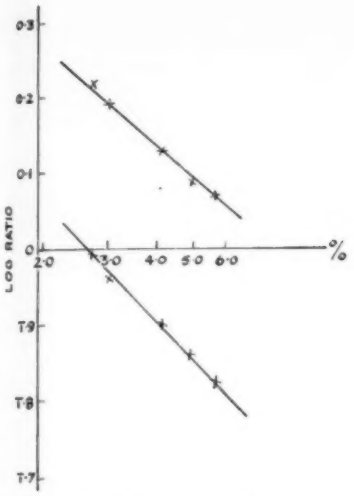


Fig. 4.—Working curves for copper (Cu 2294.4 (F), Al 2319.05).

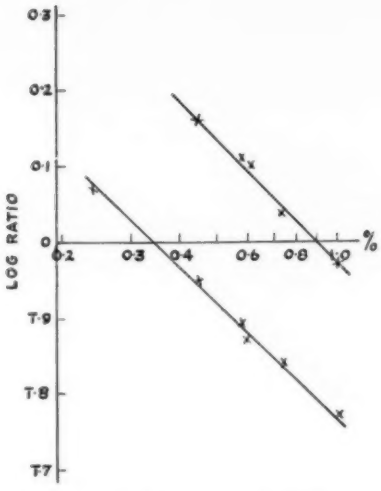


Fig. 5.—Working curves for silicon (Si 2435.16 (U), Al 2669.2).

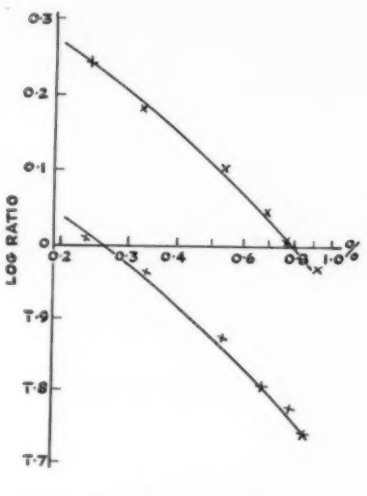


Fig. 6.—Working curves for iron (Fe 2332.8 (U), Al 2319.05).

minium alloys, it is difficult with one set of exposure conditions to select lines which not only cover the range of concentrations to be determined, but also form homologous pairs with the few available aluminium internal standard lines. It was considered, therefore, that by using a two-step filter matched pairs could be used over a wider concentration range. Also, by comparing the lines of the elements to be determined against both the filtered and unfiltered portions of the aluminium lines plate calibration could be effected by the two line pair method described by Sanders[4] for the analysis of steels.

The filter, a rhodium sputtered quartz filter, gave 100% and 48% transmission. It was fitted into a mount directly in front of the spectrographic slit, the total length of spectrum line being adjusted to 4 mm. by means of a Hartmann diaphragm. The filtered and unfiltered portions of each spectrum line were equal in length.

The exposure conditions, and the method of processing the plate which were finally selected are shown in Table I.

TABLE I.—EXPOSURE CONDITIONS

Spectrograph	Hilger Medium
Slit width	10 microns
Filter	2 step filter, 100% and 48% transmission
Source to slit distance	30 cm.
R3	Adjusted to give 3·5 amp. charging current
R2	5 ohm.
Gap width	3 mm.
Sample preparation	Flat surface, hand filed
Counter electrode	High purity graphite rod, 6 mm. diameter with 80° truncated conical tip
Photographic plate	Ilford Thin Film Half Tone
Exposure time	2 × 30 sec. superimposed
Developer	D19b (1 developer—2 water)
Development temperature	20° C.
Development time	180 sec.

Using these conditions working curves were obtained from triplicate exposures of each standard.

Two ratios were obtained for each element line, one by comparison with the unfiltered portion of the aluminium line, the other by comparison with the filtered portion of the same aluminium line. The line pairs were selected as far as possible to give log. ratios lying either side of the zero value. The working curves were obtained by plotting the log. ratio of element line deflection to aluminium line deflection against the logarithm of the percentage concentration of the element. Typical working curves are shown in Figs. 4–8. Table II gives the complete list of line pairs used.

TABLE II.—LINE PAIRS

Element Line		Internal Standard Line	Range (%)
Cu II 2247·0	U	Al 2317·48	less than 0·30
Cu II 2294·4	U	Al 2319·05	1·5–3·0
Cu II 2294·4	F	Al 2319·05	3·0–5·0
Fe II 2332·8	U	,,	0·20–1·0
Si I 2435·16	U	Al II 2669·17	0·20–1·0
Mn 2672·59	F	,,	0·20–1·0
Mg 2781·4	U	,,	less than 0·20
Mg 2781·4	F	,,	0·20–1·0
Ti II 3168·5	U	,,	0·02–0·50
Ni I 3414·8	U	Al 3059·9	0·02–0·10
Ni I 3414·8	F	,,	0·10–0·25
Zn I 3345·0	U	,,	0·05–0·20
Zn I 3345·0	F	,,	0·20–0·4
Pb I 2833·1	U	Al II 2669·17	0·03–0·20
Be I 2650·8	U	,,	0·005–0·015

U = unfiltered spectrum line.
F = filtered spectrum line.

Reproducibility

In order to ensure that the conditions used for the reproducibility tests conformed as closely as possible to those experienced in daily inspection analysis, the tests were made on a large number of plates and the work was spread over a period of about two months. Some of the exposures were in fact made on the same plates as the daily batches of inspection samples. Fifty exposures were made on each of two samples, sample *A* being exposed on nine plates and sample *B* on seven plates. No standards were exposed on the same plates as the samples.

From the percentage concentration values obtained from the working curves the Coefficient of Variation for

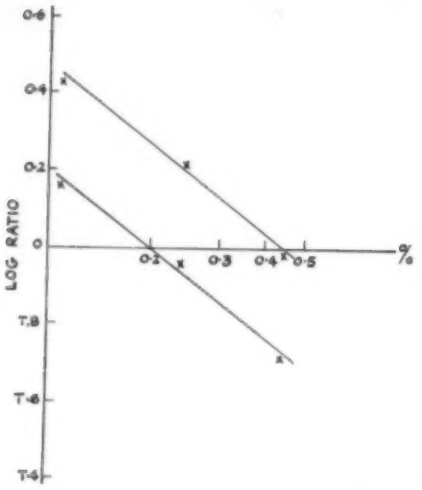


Fig. 7.—Working curves for zinc (Zn 3345 (F), Al 3059.9).

each element was calculated, and a statistical assessment of the results is shown in Tables III and IV. The

TABLE III.—RESULTS OF REPRODUCIBILITY TESTS

	Element	Cu	Mg	Si	Fe	Mn
Sample "A"	Range	1·42/1·71	0·74/0·80	0·92/1·05	0·30/0·37	0·65/0·72
	Standard Deviation	0·067	0·024	0·034	0·017	0·018
	Coeff. of Variation	4·2	3·10	3·44	5·15	2·55
	Spectrographic Analysis (average)	1·59	0·78	0·975	0·33	0·69
	Chemical Analysis	1·65	0·82	0·97	0·31	0·71
Sample "B"	Range	3·55/4·1	0·60/0·66	0·41/0·48	0·35/0·42	0·47/0·50
	Standard Deviation	0·125	0·021	0·016	0·017	0·007
	Coeff. of Variation	3·08	3·28	3·45	4·7	1·46
	Spectrographic Analysis (average)	3·71	0·64	0·46	0·38	0·48
	Chemical Analysis	3·70	0·62	0·42	0·38	0·52

TABLE IV.—RESULTS OF REPRODUCIBILITY TESTS

Element	Ti	Ni	Pb	Zn
Range	0·10/0·15	0·08/0·10	0·10/0·12	0·08/0·11
Standard Deviation ..	0·014	0·0076	0·0071	0·0084
Coeff. of Variation ..	12·0	8·5	7·1	9·3
Spectrographic Analysis (average)	0·115	0·09	0·10	0·09
Chemical Analysis ..	0·12	0·10	0·11	0·11

standard deviations obtained on samples *A* and *B* compare favourably with recent observations made using a variety of spark discharges on specially cast samples, and under conditions which do not appear to permit the percentage content of the residual elements to be determined.[6]

Applications

In order to ascertain whether the method was applicable to other types of aluminium alloys, a series of duralumin, aluminium-silicon, and "Y" alloy standards were exposed in triplicate. The two-step filter was not used since it was desired to make all the exposures on the same plate. It was found that there was some displacement of the working curves for the different types of alloys, particularly with respect to iron and silicon (Figs. 9 and 10). It is therefore necessary to employ separate working curves for the different alloys. As a plate calibration method is used, however, the working curves need only to be prepared once, since the excitation conditions are reproducible.

Samples received in the laboratory vary considerably in size, and in order to determine the effect of this variation on the analytical results a sample was sectioned to provide weights of approximately 5, 15 and 50 g. Each portion was excited under the conditions shown in Table I and the results are shown in Table V.

TABLE V.—EFFECT OF SAMPLE SIZE

Weight (g.)	Size (mm.)	Cu	Mg	Si	Fe	Mn
4·3	40 × 7 × 5	4·18 4·17 4·16 4·30	0·72 0·69 0·71 0·68	0·54 0·55 0·58 0·55	0·40 0·37 0·39 0·40	0·57 0·52 0·50 0·51
14	40 × 22 × 5	4·23 4·25 4·26 4·22	0·55 0·58 0·58 0·60	0·50 0·52 0·52 0·49	0·39 0·39 0·39 0·38	0·52 0·52 0·52 0·51
54	35 × 27 × 20	4·30 4·10 4·25 4·20	0·56 0·59 0·58 0·58	0·48 0·47 0·49 0·47	0·39 0·36 0·40 0·41	0·52 0·50 0·52 0·53
Chemical Composition		4·16	0·55	0·46	0·41	0·53

In the case of samples weighing approximately 15 g., or more, no discrepancy occurs which is greater than that which may be expected from the standard deviations given in Table III. The smallest sample shows a difference between the chemical and spectrographic figures for magnesium and silicon, which may be attributed to the effect of the excessive heating which occurs with smaller samples.

The method has been developed with reference to its applicability and general usefulness in inspection analysis, and Table VI indicates the information which can be derived from a single exposure made under the conditions listed in Table I. Comparison with chemical analysis over a lengthy period has not revealed serious discrepancies between results obtained by the two methods.

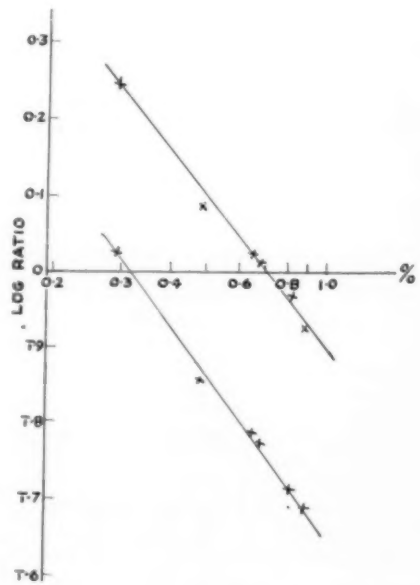


Fig. 8.—Working curves for magnesium (Mg 2781.4 (F). Al 2669.2).

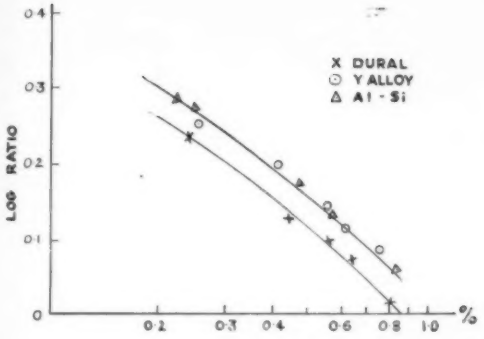


Fig. 9.—Working curves for iron in duralumin, Y-alloy and an aluminium-silicon alloy (Fe 2332.8, Al 2319.05).

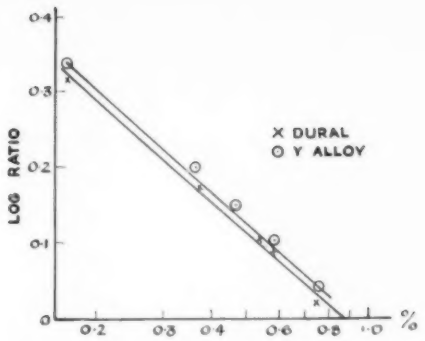


Fig. 10.—Working curves for silicon in duralumin and Y-alloy (Si 2435.16, Al 2669.2).

TABLE VI.—INFORMATION TO BE DERIVED FROM A SINGLE EXPOSURE

Material Specification	Elements Determined Quantitatively
A.W. 15	Mg, Si, Mn, Fe Residuals (Ni, Zn, Pb, Ti, etc.)
A.W. 14	Si, Fe, Ti, Pb Residuals
A.W. 2	Fe Residuals
A.W. 3	Fe, Si, Cu Residuals
A.W. 4–7	Cu, Si, Mn, Fe
A.W. 10	Mg, Fe, Si, Mn Residuals

It is considered that absence of marked effects due to the metallurgical history of the sample arises from the fact that there is a vigorous attack on the sample under the excitation conditions employed. This is shown in Fig. 11, in which the type of crater obtained with the A.C. arc (*a*) is compared with a crater obtained using the uncontrolled condensed spark discharge (*b*).

Conclusion

The method described in this paper indicates the general utility of the low-voltage intermittent A.C. arc for the analysis of aluminium alloys with the minimum amount of sample preparation. The use of the two-step filter ensures that adequate sensitivity for the determination of small concentrations of impurities is combined with a satisfactory order of reproducibility over a wide range of element concentrations.

Acknowledgments

The authors wish to thank the Superintending Scientist, Bragg Laboratory, for the facilities provided to undertake the investigation, and the Admiralty for permission to publish the report.

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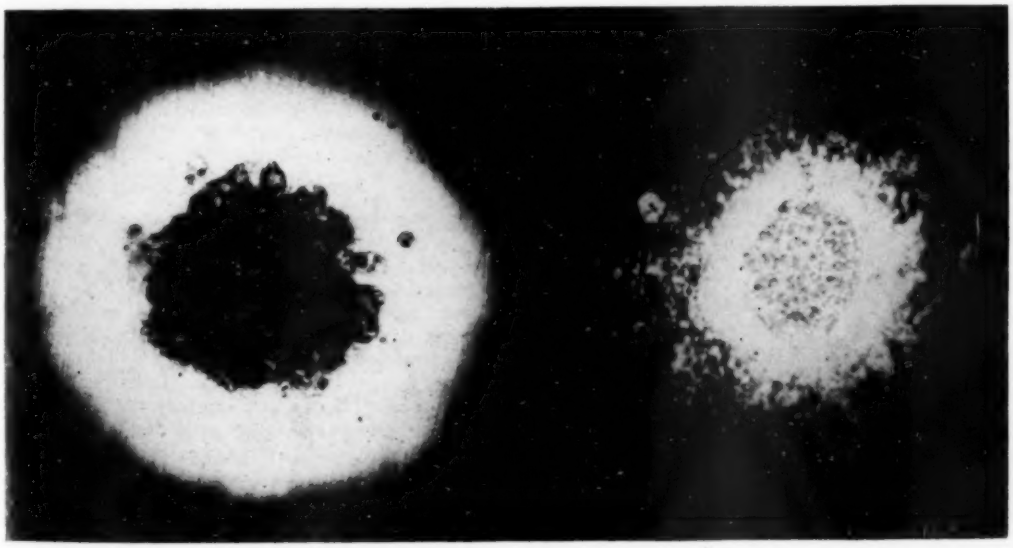


Fig. 11.—Photograph (×8) of craters produced by (a) an intermittent A.C. arc, and (b) an uncontrolled condensed spark discharge.

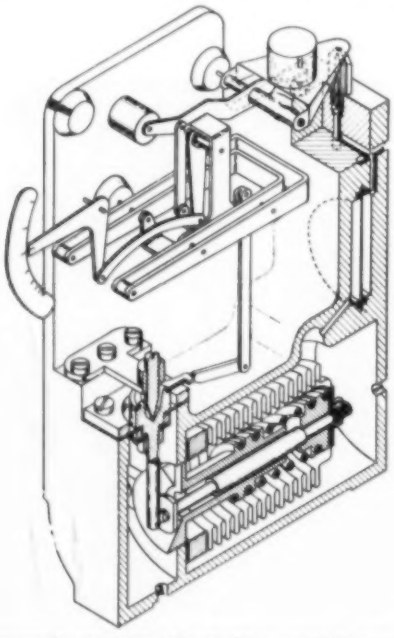
Items of Metallurgical Interest at Recent Instrument Exhibitions

The recent Instruments, Electronics and Automation Exhibition at Olympia aroused considerable interest, as might be expected at a time when automatic devices are finding increasing application in industry and commerce. In this series of articles, reference is made to items of metallurgical interest exhibited at Olympia, and at the Physical Society Exhibition which, as usual, provided an opportunity for the display of new commercially available and prototype instruments and laboratory equipment.

Automatic Control Units

CONTINUING research on their Mark 20 system of air-operated automatic control equipment enabled George Kent to introduce to Olympia visitors a number of new facilities designed to give greater stability, simpler adjustment and operation, larger application, and better performance. These included a control unit, a reducing valve, an air relay, and an A.M.T.S. panel.

The improved design of the Mark 20 controlling unit embodies a stabilising feed-back link between the nozzle and the bellows chamber, in parallel with the normal feed-back circuit via the relay and derivative valve resistance. It comprises a passage-way, between nozzle and bellows chamber, intersected by a diaphragm, the stiffness of which is arranged so that approximately 1 or 2% of a pressure change at the nozzle is felt in the bellows chamber. The change occurs with extremely small dead time, giving a much higher degree of stability to the mechanism. This permits greater air-output quantities to the regulating unit. The small feed-back effect (1 or 2%) theoretically reduces the phase advance provided by the derivative resistance contained in the normal feed-back circuit, but in practice the loss is negligible.

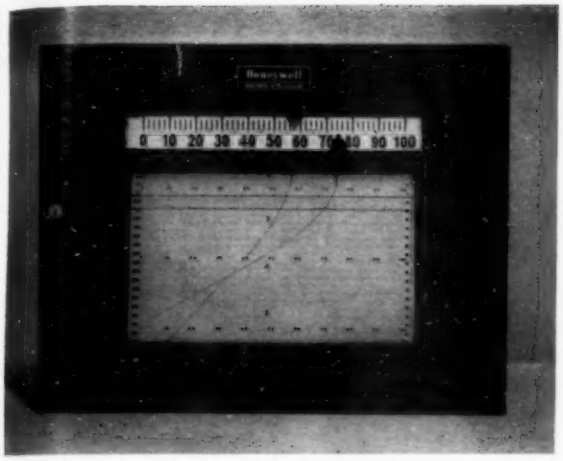


Section through new Kent Mark 20 controlling unit. The new passageway is shown in the wall on the centre right.

The A.M.T.S. panel is an auto/manual/test/service panel with an edgewise indicating gauge providing for easy reversal for air-pressure change; the gauge can always provide a scale which indicates regulating unit position such that the controlled condition is being increased when the gauge pointer moves from left to right. The manual regulator like the new reducing valve, can be arranged to increase the value of the controlled condition for a clockwise direction of rotation. The selector valve provides a choice of four positions: the first gives fully automatic working, and the second remote manual operation with the integral action cancelled and held at a value equal to the manual signal. The "test" position permits remote manual control of the regulating unit, and also provides conditions which allow the controlling unit to be aligned and the integral- and derivative-action times to be checked. The "service" position permits remote manual operation of the regulating unit, but isolates the controlling unit from the air system, so that it can be removed for service. The selector valve may be fitted with single-pole changeover electric contacts to operate on "auto" or "auto" and "test" positions. This enables electrically initiated functions to be employed, e.g., where one controller has to actuate a number of regulating units, each of which is required to have the manual control facility, the last regulating unit to be switched to manual control can fix the integral-action signal, and so prevent integral saturation during the period the plant is on manual control.

Special Purpose Recorders

Among the wide range of instruments exhibited at Olympia by Honeywell-Brown, Ltd., was a series of strip and circular chart potentiometer recorders which included two special purpose models. The ¼ second pen speed recorder has an electronic null-balance servo measuring system incorporating a newly designed "plug-in" amplifier with a high input impedance and output power. The amplifier output drives a new type of balancing motor having a no-load speed of 1,650 r.p.m. The design refinements of the motor, amplifier and slidewire assembly produce a pen speed giving full 11-in. scale travel in ¼ second. A tachometer circuit provides damping which is strictly a function of pen speed, and is adjustable by means of a rheostat. This recorder has been developed to meet the needs of scientists and engineers to record rapidly changing variables.



Honeywell-Brown Duplex Electronik strip chart recorder.

The simultaneous recording of two independent variables on a common chart facilitates many analyses involving comparison measurement. To meet the need for equipment for this purpose, Honeywell-Brown have developed the Duplex recorder, which is virtually two orthodox instruments built into the same case. The two pens are entirely independent, and traverse the full width of the scale without interfering with each other. Since the two measuring circuits are separate, the actuation and range of each pen can be the same or totally different. A further advantage is the optional provision of a Selsyn-type chart drive motor which allows the two variables to be recorded as a function of motion or displacement. For example, on strip rolling mills, temperature and thickness of the strip can be recorded against the length of strip having passed through the mill.

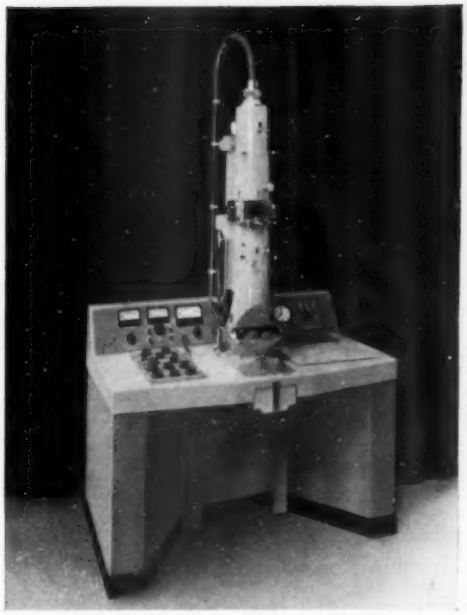
Electron Microscope

The Metropolitan-Vickers Type EM6 electron microscope is designed to attain an instrumental resolving power of 15 Å., or better, and incorporates facilities for transmission and reflection microscopy and microdiffraction. The electron optical system consists of a fully adjustable electron gun, operating at 50, 75 or 100 kV., followed by two condenser lenses, an electronic beam alignment stage, water cooled objective, intermediate and final projector lenses. The condenser lenses enable fine illuminating spots to be obtained, and direct magnifications ranging from 1,000× to 100,000× are possible. When the beam accelerating voltage is changed, the lens excitation currents are automatically adjusted so as to maintain a constant image magnification.

All controls are mounted conveniently at hand on the microscope desk, and the viewing chamber is generously proportioned to permit several persons to see the viewing screen at one time. The camera normally accommodates a six-plate mechanism with air-lock entry. The high voltage D.C. supply is derived from a metal rectifier voltage multiplier, of the Cockroft-Walton type, housed in a separate cubicle.

Recording Gas Calorimeter

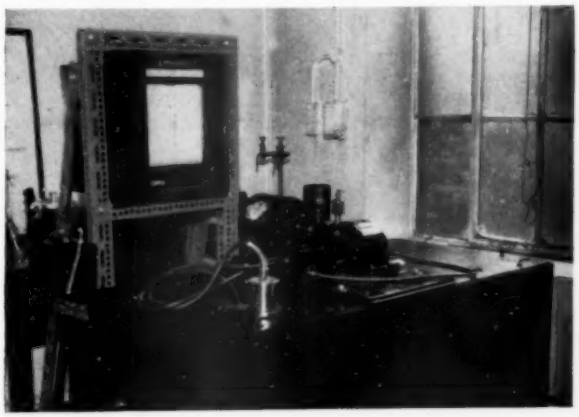
The Cambridge-Thomas recording gas calorimeter shown by the Cambridge Instrument Co., Ltd., at the



The Metropolitan-Vickers EM6 electron microcope.

Physical Society Exhibition, is of the flow type in which the heat transfer medium is air. It gives results directly in B.Th.U./cu. ft. (or k.-Cal./cu. m.) at any standard condition of temperature, pressure and humidity, and performance is totally unaffected by any variation of these characteristics. The calorimeter is sensitive to changes of less than 0·25 B.Th.U./cu. ft., and the guaranteed accuracy is within ±0·5% of the range value. The full coverage ranges from 70 to 2,400 B.Th.U./cu. ft. (700 to 24,000 k.-Cal./cu. m.).

The recording element consists of a Cambridge electronic recorder arranged as a self-balancing A.C. bridge. Differentially arranged resistance thermometers measure the temperature rise of the cooling air. Such changes are directly proportional to changes in calorific value of the sample gas. Up to four separate ranges can be provided on one instrument, and the improved response time increases the value of the calorimeter as



The Cambridge-Thomas recording gas calorimeter.

the measuring element in automatic three-term control systems for gas mixing problems.

The instrument does not require checking against a standard calorimeter and can be independently tested by burning hydrogen. Calibration is maintained over long periods and very little maintenance is required.

Pellicle Plastic Replicas

The interference microscope can be used to measure surface variations in flatness up to 40 or 50 micro-inches, but with irregularities greater than this the fringe pattern is difficult to interpret. The pellicle plastic replica technique demonstrated at the Physical Society Exhibition by Hilger & Watts, Ltd., serves to increase the range of the two-beam instruments by increasing the value of the fringe spacing, and it can be used for any type of surface, not necessarily a reflecting surface. The value of the fringe spacing depends upon the difference of the refractive indices of the plastic material from which the pellicle is made, and the fluid—which may be air or liquid—in which the pellicle is immersed during observation with the microscope. The method followed is to make a very thin transparent pellicle of the surface by flowing on to it a plastic solution in a very liquid state. The top of the liquid should be smoothed off with a knife edge before drying takes place. When the pellicle is dried it can be stripped from the surface and will be a negative, that is, scratches in the original surface will become raised places in the pellicle. This pellicle is now mounted on the platform of the two beam microscope facing downwards on an optical flat with a highly reflecting surface (aluminised). This surface is then viewed by means of the microscope through the pellicle. For greater efficiency there should be a film of liquid, e.g., water, paraffin, glycerine, etc., between the pellicle and the reflecting flat. Since the value of the fringe spacing instead of being half the wavelength of the light used is now half the wavelength divided by the difference of the refractive indices of the pellicle and the immersion fluid, it is possible by choosing substances with suitable refractive indices to have a fringe spacing which is convenient for use with the surface to be examined. This value can be as much as 100 micro-inches.

Progress with the Five Year Plan

D.S.I.R. Annual Report, 1955-56

AS in previous years, by far the largest part of the D.S.I.R. Annual Report 1955–56 consists of accounts of items of research selected from the programmes of the Department's research establishments, and of summaries of the work of the grant-aided co-operative industrial research organizations. There are also a number of appendices to the report which contain a summary of the Department's expenditure during the year, details of maintenance allowances paid to post-graduate students, and grants for special researches in universities. A full list of the publications of both the departmental establishments and the research associations is also included.

Financial Matters

Steady progress has been made along the path laid down in the five-year plan, nevertheless, in one respect, i.e. in relation to capital expenditure on buildings, the Department was called upon to make a contribution to economy in public expenditure. Two new building projects were deferred—an experimental road system, being the first part of the new Road Research Laboratory at Crowthorne, Berks ; and a new chemistry building at the Building Research Station at Watford. On the other hand, major projects already building, including the new ship tank for the National Physical Laboratory and buildings for the Mechanical Engineering Research Laboratory at East Kilbride, were carried on without change.

The Council is at pains to point out that any impression that it is " intensely dissatisfied with a position which could be readily remediable by the allocation of additional resources " would be misunderstanding. It does not deny discontent with the volume of resources available to meet the legitimate claims of the Department's work, but it recognises that there are many other claims on money and men. The Council states that " . . . we must and do accept that we cannot expect to see everything done which we believe to be fully justifiable when looked at from a limited departmental standpoint. It would be otherwise if there were available a body of unused scientific resources."

Help for Universities

For some years the D.S.I.R. has been providing resources needed in various universities for nuclear physics research, including especially the heavy and unpredictable cost of running large machines for accelerating nuclear particles. It had always been the intention to review this position and this has now been done. After discussion with the University Grants Committee, it was agreed that the D.S.I.R. would continue to provide support for certain machines on a year to year basis, but the support will be confined to the maintenance of the machines, the provision of technicians and the cost of electric power, cooling water and refrigerants. The cost of research becomes the universities' responsibility.

The finances of the Radio Telescope at Jodrell Bank are mentioned in the Report. The final cost is likely to be about a quarter of a million pounds over the amounts of the grants offered so far. The Council regarded the project as so important scientifically that it recommended that a further Government grant be made to help to meet the deficit.

£300,000 Locomotive Order

YORKSHIRE ENGINE CO., LTD., Sheffield, a subsidiary of The United Steel Cos., Ltd., have secured an order valued at about £300,000 for the supply of twelve 400 h.p. *Janus* diesel-electric shunting locomotives to the Billingham Division of Imperial Chemical Industries, Ltd.

Microfinishing Machine Agency

WICKMAN, LTD., announce their recent appointment as sole agents in the United Kingdom for the range of microfinishing machines manufactured by Maschinenfabrik Ernst Thielenhaus, Wuppertal-Barmen, Germany.